

FIG. 1

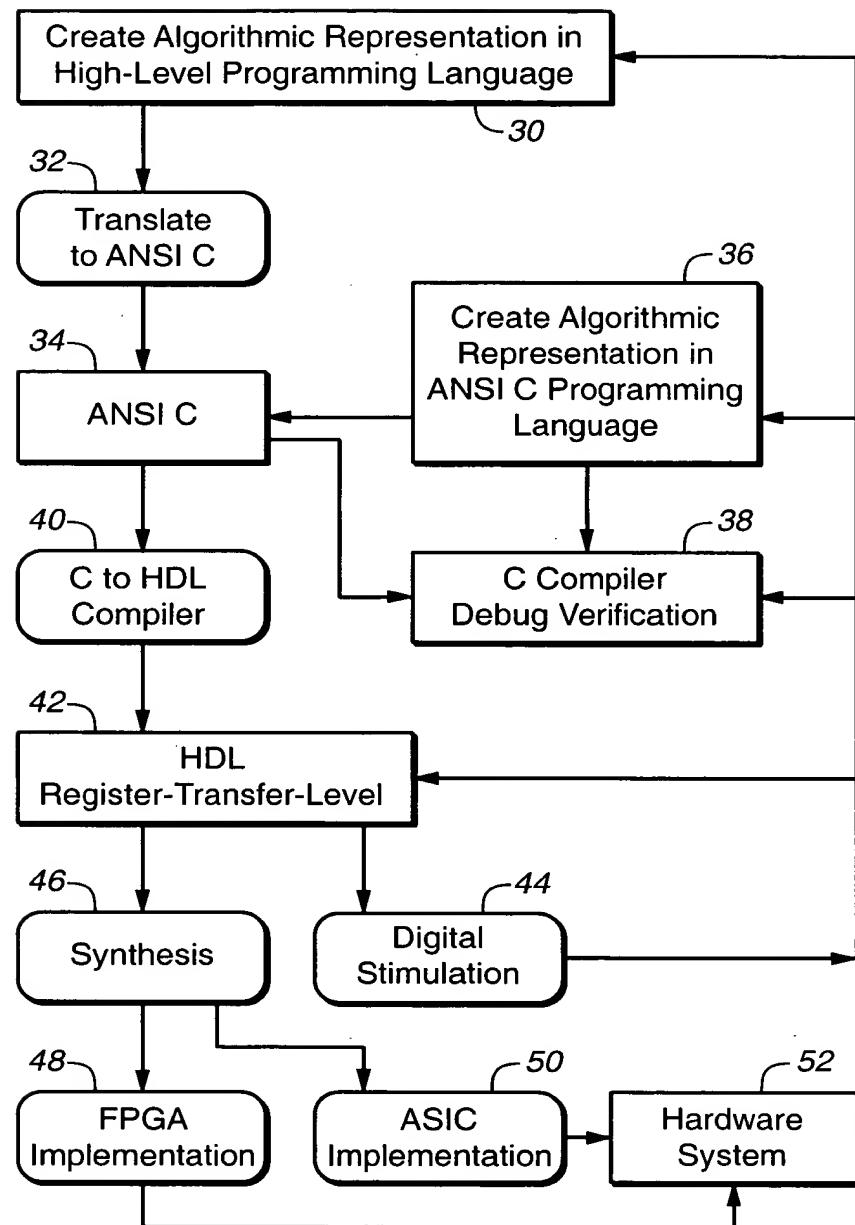


FIG._2

```
int func1 (unsigned a, unsigned b, unsigned c)
{
    return a + b ^ c << 3;
}

int func2 (int a, int b, int c)
{
    return (a ^ b) & c;
}
```

FIG._3A

```
module func1(result_func1, result_func2, param_func1_a, param_func1_b,
            param_func1_c, param_func2_a, param_func2_b, param_func2_c);

    output [15:0]    result_func1, result_func2;
    input  [15:0]    param_func1_a, param_func1_b, param_func1_c;
    input  [15:0]    param_func2_a, param_func2_b, param_func2_c;

    wire  [15:0]    result_func1 =
                    ((param_func1_a + param_func1_b) ^ (param_func1_c << 16'd3));
    wire  [15:0]    result_func2 =
                    ((param_func2_a ^ param_func2_b) & param_func2_c);

endmodule
```

FIG._3B

```
int func1 (unsigned a, unsigned b, unsigned c)
{
    return a + (b == 1) ^ c << 3;
}

int func2 (int a, int b, int c)
{
    if (a < b)
        c -= b;

    return (a ^ b) & c;
}

int func3 (unsigned a, unsigned b, int c)
{
    unsigned d = 0;
    unsigned e;

    b++;

    if (a < b)
    {
        int c = e = a - b;

        if (a != 0)
        {
            c -= a & b;
            d = c++ ^ b;
        }
        else
        {
            d++;
            e = c + d ? c : 1;
        }
    }
    d = 1;
    return a < b && (a + b ^ c != 3 || a - b == 0);
}
```

FIG._4A

```

module funcx (clock,result_func1,result_func2,result_func3,param_func1_a,
param_func1_b,param_func1_c,param_func2_a,param_func2_b,
param_func2_c,param_func3_a,param_func3_b,param_func3_c);
input      clock;
input [15:0] param_func1_a, param_func1_b, param_func1_c, param_func2_a, param_func2_b,
           param_func2_c, param_func3_a, param_func3_b, param_func3_c;
output [15:0] result_func1, result_func2, result_func3;
reg      _5_1;
reg [15:0] result_func1, result_func2, result_func3,
           _func2_c, _func3_b, _6_func3_d, _6_func3_e,
           _7_func3_c, _1_16, _4_16, _6_16, _7_16;
reg [16:0] _2_17, _3_17;
always @(posedge clock)
begin
    _1_16 = (param_func1_b == 16'd1);
    result_func1 = ((param_func1_a + _1_16) ^ (param_func1_c << 16'd3));
    _func2_c = param_func2_c;
    _2_17 = { ~param_func2_a [15], param_func2_a };
    _3_17 = { ~param_func2_b [15], param_func2_b };
    if (_2_17 < _3_17)
        _func2_c = (_func2_c - param_func2_b);
    result_func2 = ((param_func2_a ^ param_func2_b) & _func2_c);
    _func3_b = param_func3_b;
    _6_func3_d = 16'd0;
    _func3_b = (_func3_b + 16'd1);
    if ((param_func3_a < _func3_b))
        begin
            _6_func3_e = (param_func3_a - _func3_b);
            _7_func3_c = _6_func3_e;
            if ((param_func3_a != 16'd0))
                begin
                    _7_func3_c = (_7_func3_c - (param_func3_a & _func3_b));
                    _4_16 = _7_func3_c;
                    _7_func3_c = (_4_16 + 16'd1);
                    _6_func3_d = (_4_16 ^ _func3_b);
                end
            else
                begin
                    _6_func3_d = (_6_func3_d + 16'd1);
                    _6_func3_e = (_7_func3_c + _6_func3_d) ? _7_func3_c : 16'd1;
                end
        end
    _6_func3_d = 16'd1;
    _6_16 = (param_func3_c != 16'd3);
    _5_1 = (param_func3_a < _func3_b) && (((param_func3_a + _func3_b) ^ _6_16)
        || ((param_func3_a - _func3_b) == 16'd0));
    _7_16 = _5_1;
    result_func3 = _7_16;
end
endmodule

```

FIG._ 4B

```
int sum1 (int n)
{
    int i, sum = 0;
    for (i = 0; i < n; i++)
        sum += i;
    return sum;
}

int sum2 (int array [], int size)
{
    int i, sum = 0;
    for (i = 0; i < size; i++)
        sum += array [i];
    return sum;
}

int main ()
{
    int i;
    int array [10];
    int size = sizeof (array) / sizeof (*array);
    for (i = 0; i < size; i++)
        array [i] = i * 2;
    return sum1 (size) + sum2 (array, size);
}
```

FIG._5A

```

`define _5_main_array 4'h1

module RAM32X1 (O, D, WE, A4, A3, A2, A1, A0);
/* synthesis black_box xc_alias="RAM" */
    input      D, WE, A4, A3, A2, A1, A0;
    output     O;
    reg [31:0] d;
    wire [4:0]  A = { A4, A3, A2, A1, A0 };
    assign     O = d [A];
    always @(A or D or WE)
        if (WE)
            d [A] = D;
endmodule

module RAM32x1 (a, d, o, we);
    input [4:0] a;
    input      d, we;
    output     o;
    RAM32X1 RAM32X1 (o, d, we, a [4], a [3], a [2], a [1], a [0]);
endmodule

module RAM32x16 (a, d, o, we);
    input      we;
    input [4:0] a;
    input [15:0] d;
    output [15:0] o;
    RAM32x1 U0 (a, d [ 0], o [ 0], we);
    RAM32x1 U1 (a, d [ 1], o [ 1], we);
    RAM32x1 U2 (a, d [ 2], o [ 2], we);
    RAM32x1 U3 (a, d [ 3], o [ 3], we);
    RAM32x1 U4 (a, d [ 4], o [ 4], we);
    RAM32x1 U5 (a, d [ 5], o [ 5], we);
    RAM32x1 U6 (a, d [ 6], o [ 6], we);
    RAM32x1 U7 (a, d [ 7], o [ 7], we);
    RAM32x1 U8 (a, d [ 8], o [ 8], we);
    RAM32x1 U9 (a, d [ 9], o [ 9], we);
    RAM32x1 U10 (a, d [10], o [10], we);
    RAM32x1 U11 (a, d [11], o [11], we);
    RAM32x1 U12 (a, d [12], o [12], we);
    RAM32x1 U13 (a, d [13], o [13], we);
    RAM32x1 U14 (a, d [14], o [14], we);
    RAM32x1 U15 (a, d [15], o [15], we);
endmodule

module RAM11x16 (a, d, o, we);
    input      we;
    input [3:0] a;
    input [15:0] d;
    output [15:0] o;
    RAM32x16 U ((1'b0, a), d, o, we);
endmodule

```

FIG._5B1

```

module for1 (clock, reset, result_sum1, result_sum2, result_main,
            param_sum1_n, param_sum2_array, param_sum2_size, run_sum1,
            ready_sum1, run_sum2, ready_sum2, run_main, ready_main);

    input      clock, reset, run_sum1, run_sum2, run_main;
    input [15:0] param_sum1_n, param_sum2_array, param_sum2_size;
    output     ready_sum1, ready_sum2, ready_main;
    output [15:0] result_sum1, result_sum2, result_main;
    reg       [15:0] result_sum1, result_sum2, result_main;
    reg       ready_sum1, ready_sum2, ready_main, we;
    wire      [15:0] o, d;
    reg       [ 3:0] state, a, return_state_sum1, return_state_sum2;
    reg       [15:0] _sum1_n, _2_sum1_i, _2_sum1_sum, _sum2_array, _sum2_size;
    reg       [15:0] _4_sum2_i, _4_sum2_sum, _5_main_i, _5_main_size, _5_16, _8_16;
    reg       [16:0] _1_17, _2_17, _3_17, _4_17, _6_17, _7_17;

    RAM11x16 m (a, d, o, we);
    parameter _sum1 = 1, _sum2 = 5;

    always @(posedge clock)
    begin
        if (reset)
        begin
            we = 0;
            state = 0;
        end
        else
        begin
            case (state)
                0: begin
                    if (run_sum1)
                    begin
                        ready_sum1 = 0;
                        return_state_sum1 = 0;
                        _sum1_n = param_sum1_n;
                        state = _sum1;
                    end
                    else if (run_sum2)
                    begin
                        ready_sum2 = 0;
                        return_state_sum2 = 0;
                        _sum2_array = param_sum2_array;
                        _sum2_size = param_sum2_size;
                        state = _sum2;
                    end
                    else if (run_main)
                    begin
                        ready_main = 0;
                        _5_main_size = 16'd10;
                        _5_main_i = 16'd0;
                        state = 9;
                    end
                end
            end
        end
    end

```

FIG._5B2

```

    _sum1: begin
        _2_sum1_sum = 16'd0;
        _2_sum1_i = 16'd0;
        state = 2;
    end
    2: begin
        _1_17 = { ~ _2_sum1_i [15], _2_sum1_i };
        _2_17 = { ~ _sum1_n [15], _sum1_n };
        state = (_1_17 < _2_17) ? 3 : 4;
    end
    3: begin
        _2_sum1_sum = (_2_sum1_sum + _2_sum1_i);
        _2_sum1_i = (_2_sum1_i + 16'd1);
        state = 2;
    end
    4: begin
        result_sum1 = _2_sum1_sum;
        ready_sum1 = 1;
        state = return_state_sum1;
    end
    sum2: begin
        _4_sum2_sum = 16'd0;
        _4_sum2_i = 16'd0;
        state = 6;
    end
    6: begin
        _3_17 = { ~ _4_sum2_i [15], _4_sum2_i };
        _4_17 = { ~ _sum2_size [15], _sum2_size };
        state = (_3_17 < _4_17) ? 7 : 8;
    end
    7: begin
        a = (_sum2_array + _4_sum2_i);
        state = 12;
    end
    12: begin
        _5_16 = 0;
        _4_sum2_sum = (_4_sum2_sum + _5_16);
        _4_sum2_i = (_4_sum2_i + 16'd1);
        state = 6;
    end
    8: begin
        result_sum2 = _4_sum2_sum;
        ready_sum2 = 1;
        state = return_state_sum2;
    end
    9: begin
        _6_17 = { ~ _5_main_i [15], _5_main_i };
        _7_17 = { ~ _5_main_size [15], _5_main_size };
        state = (_6_17 < _7_17) ? 10 : 11;
    end

```

```
10: begin
    _8_16 = (_5_main_i << 1'd1);
    a = (_5_main_array + _5_main_i);
    d = _8_16;
    we = 1;
    state = 13;
end
13: begin
    we = 0;
    _5_main_i = (_5_main_i + 16'd1);
    state = 9;
end
11: begin
    _sum1_n = _5_main_size;
    return_state_sum1 = 14;
    state = _sum1;
end
14: begin
    _sum2_array = `_5_main_array;
    _sum2_size = _5_main_size;
    return_state_sum2 = 15;
    state = _sum2;
end
15: begin
    result_main = (result_sum1 + result_sum2);
    ready_main = 1;
    state = 0;
end
default: ;
endcase
end
endmodule
```

FIG._5B4

```
#include <stdio.h>

void main ()
{
    int a, b;
    scanf ("%d %d", &a, &b);
    printf ("a + b = %d\n", a + b);
}
```

FIG._6A

```
module Printf (clock, scanf_0_1_line_19_a, scanf_0_2_line_19_b, printf_1_1_line_20, run_main);
    input      clock, run_main;
    input [15:0] scanf_0_1_line_19_a, scanf_0_2_line_19_b;
    output [15:0] printf_1_1_line_20;
    reg   [15:0] printf_1_1_line_20, _3_main_a, _3_main_b;

    always @(posedge clock)
        begin
            if (run_main)
                begin
                    _3_main_a = scanf_0_1_line_19_a;
                    _3_main_b = scanf_0_2_line_19_b;
                    printf_1_1_line_20 = (_3_main_a + _3_main_b);

                    // User Verilog code
                    $write ("a + b = %d\n", printf_1_1_line_20);
                    // End of user Verilog code
                end
        end
endmodule
```

FIG._6B

```
int func (a, b, c, d)
{
    return (a / b + c / d);
}
```

FIG._7A

```
module udivmod16 (a, b, div, mod);
    input [15:0] a, b;
    output [15:0] div, mod;
    reg [15:0] div, mod, pa0, pa1, pa2, pa3, pa4, pa5, pa6, pa7, pa8, pa9, pa10, pa11, pa12,
                pa13, pa14, pa15, pa16, shb0;
    reg [16:0] shb1;
    reg [17:0] shb2;
    reg [18:0] shb3;
    reg [19:0] shb4;
    reg [20:0] shb5;
    reg [21:0] shb6;
    reg [22:0] shb7;
    reg [23:0] shb8;
    reg [24:0] shb9;
    reg [25:0] shb10;
    reg [26:0] shb11;
    reg [27:0] shb12;
    reg [28:0] shb13;
    reg [29:0] shb14;
    reg [30:0] shb15;

    always @(a or b)
    begin
        pa0 = a;

        shb15 = b << 15;
        div [15] = pa0 >= shb15;
        pa1 = div [15] ? pa0 - shb15 : pa0;

        shb14 = b << 14;
        div [14] = pa1 >= shb14;
        pa2 = div [14] ? pa1 - shb14 : pa1;

        shb13 = b << 13;
        div [13] = pa2 >= shb13;
        pa3 = div [13] ? pa2 - shb13 : pa2;
```

FIG._7B1

```

shb12 = b << 12;
div [12] = pa3 >= shb12;
pa4 = div [12] ? pa3 - shb12 : pa3;

shb11 = b << 11;
div [11] = pa4 >= shb11;
pa5 = div [11] ? pa4 - shb11 : pa4;

shb10 = b << 10;
div [10] = pa5 >= shb10;
pa6 = div [10] ? pa5 - shb10 : pa5;

shb9 = b << 9;
div [9] = pa6 >= shb9;
pa7 = div [9] ? pa6 - shb9 : pa6;

shb8 = b << 8;
div [8] = pa7 >= shb8;
pa8 = div [8] ? pa7 - shb8 : pa7;

shb7 = b << 7;
div [7] = pa8 >= shb7;
pa9 = div [7] ? pa8 - shb7 : pa8;

shb6 = b << 6;
div [6] = pa9 >= shb6;
pa10 = div [6] ? pa9 - shb6 : pa9;

shb5 = b << 5;
div [5] = pa10 >= shb5;
pa11 = div [5] ? pa10 - shb5 : pa10;

shb4 = b << 4;
div [4] = pa11 >= shb4;
pa12 = div [4] ? pa11 - shb4 : pa11;

shb3 = b << 3;
div [3] = pa12 >= shb3;
pa13 = div [3] ? pa12 - shb3 : pa12;

shb2 = b << 2;
div [2] = pa13 >= shb2;
pa14 = div [2] ? pa13 - shb2 : pa13;

shb1 = b << 1;
div [1] = pa14 >= shb1;
pa15 = div [1] ? pa14 - shb1 : pa14;

shb0 = b << 0;
div [0] = pa15 >= shb0;
pa16 = div [0] ? pa15 - shb0 : pa15;

mod = pa16;
end
endmodule

```

```

module sdivmod16 (a, b, div, mod);

    input [15:0] a, b;
    output [15:0] div, mod;

    wire [15:0] ua = a [15] ? - a : a;
    wire [15:0] ub = b [15] ? - b : b;
    wire [15:0] udiv, umod;

    udivmod16 udivmod (ua, ub, udiv, umod);

    wire [15:0] div = (a [15] != b [15]) ? - udiv : udiv;
    wire [15:0] mod = a [15] ? - umod : umod;

endmodule

```

TOPLEVEL DESIGN

```

module DivEx (clock,reset,result_func,param_func_a,param_func_b,
             param_func_c,param_func_d,run_func,ready_func);

    input      clock, reset, run_func;
    input [15:0] param_func_a, param_func_b, param_func_c, param_func_d;
    output     ready_func;
    output [15:0] result_func;

    reg [15:0] result_func, divmod_a, divmod_b, _1_16, _2_16;
    reg        ready_func;
    reg [1:0]   state;
    wire [15:0] div_result;

    sdivmod16 sdivmod (divmod_a, divmod_b, div_result, );

    always @(posedge clock)
    begin
        if (reset)
            state = 0;
        else
            begin
                case (state)
                    0: begin
                        if (run_func)
                            begin
                                ready_func = 0;
                                divmod_a = param_func_a;
                                divmod_b = param_func_b;
                                state = 1;
                            end
                        end
                    end
                end
            end
    end

```

FIG._7B3

```
1: begin
    _1_16 = div_result;
    divmod_a = param_func_c;
    divmod_b = param_func_d;
    state = 2;
end

2: begin
    _2_16 = div_result;
    result_func = (_1_16 + _2_16);
    ready_func = 1;
    state = 0;
end

default: ;

endcase
end
end

endmodule
```

FIG._7B4

```
int data_in;
int out1;
int out2;
int data_out;

void pipeline_stage_1 ()
{
    out1 = data_in + 1;
}

void pipeline_stage_2 ()
{
    out2 = out1 + out1;
}

void pipeline_stage_3 ()
{
    data_out = out2 ^ 1234;
}

#ifndef __SYNETRY__
#include <stdio.h>

void main ()
{
    for (;;)
    {
        scanf ("%d", & data_in);

        pipeline_stage_1 ();
        pipeline_stage_2 ();
        pipeline_stage_3 ();

        printf ("%d", data_out);
    }
}
#endif
```

FIG._8A

```
module Pipeline (clock, _data_in, _data_out, run_pipeline_stage_1, run_pipeline_stage_2,
run_pipeline_stage_3);
    input      clock, run_pipeline_stage_1, run_pipeline_stage_2, run_pipeline_stage_3;
    input [15:0] _data_in;
    output [15:0] _data_out;
    reg   [15:0] _data_out, _out1, _out2;
    always @(posedge clock)
    begin
        if (run_pipeline_stage_1)
            _out1 = (_data_in + 16'd1);
    end
    always @(posedge clock)
    begin
        if (run_pipeline_stage_2)
            _out2 = (_out1 + _out1);
    end
    always @(posedge clock)
    begin
        if (run_pipeline_stage_3)
            _data_out = (_out2 ^ 16'd1234);
    end
endmodule
```

FIG._8B

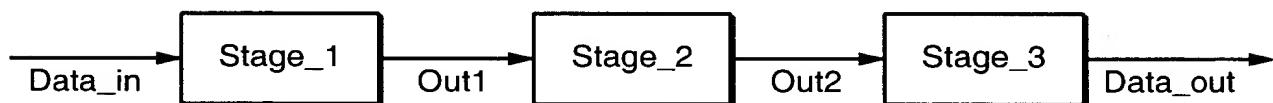


FIG._8C

```
int func (float a, double b, long double c, int i)
{
    return - a + b * c - 16.5 / c;
}
```

FIG._9A

DESIGN DOCUMENT

```
module Float (clock,reset,zero_substractor_float_operand,
    zero_substractor_float_run,zero_substractor_float_ready,zero_substractor_float_result,
    convertor_from_float_to_long_double_operand,convertor_from_float_to_long_double_run,
    convertor_from_float_to_long_double_ready,convertor_from_float_to_long_double_result,
    convertor_from_double_to_long_double_operand,convertor_from_double_to_long_double_run,
    convertor_from_double_to_long_double_ready,convertor_from_double_to_long_double_result,
    multiplier_long_double_a,multiplier_long_double_b,multiplier_long_double_run,
    multiplier_long_double_ready,multiplier_long_double_result,adder_long_double_a,
    adder_long_double_b,adder_long_double_run,adder_long_double_ready,adder_long_double_result,
    divider_long_double_a,divider_long_double_b,divider_long_double_run,
    divider_long_double_ready,divider_long_double_result,subtractor_long_double_a,
    subtractor_long_double_b,subtractor_long_double_run,subtractor_long_double_ready,
    subtractor_long_double_result,convertor_from_long_double_to_signed_16_operand,
    convertor_from_long_double_to_signed_16_run,convertor_from_long_double_to_signed_16_ready,con
    vertor_from_long_double_to_signed_16_result,result_func,param_func_a,param_func_b,
    param_func_c,param_func_i,run_func,ready_func);
```

input	clock, reset, zero_substractor_float_ready, convertor_from_float_to_long_double_ready,
	convertor_from_double_to_long_double_ready, multiplier_long_double_ready,
	adder_long_double_ready, divider_long_double_ready, subtractor_long_double_ready,
	convertor_from_long_double_to_signed_16_ready, run_func;
input [15:0]	convertor_from_long_double_to_signed_16_result, param_func_i;
input [31:0]	zero_substractor_float_result, param_func_a;
input [63:0]	param_func_b;
input [79:0]	convertor_from_float_to_long_double_result, param_func_c,
	convertor_from_double_to_long_double_result, multiplier_long_double_ready,
	adder_long_double_result, divider_long_double_result, subtractor_long_double_result;
output	zero_substractor_float_run, convertor_from_float_to_long_double_run,
	convertor_from_double_to_long_double_run, multiplier_long_double_run,
	adder_long_double_run, divider_long_double_run, subtractor_long_double_run,
	convertor_from_long_double_to_signed_16_run, ready_func;
output [15:0]	result_func;
output [31:0]	zero_substractor_float_operand, convertor_from_float_to_long_double_operand;
output [63:0]	convertor_from_double_to_long_double_operand;
output [79:0]	multiplier_long_double_a, multiplier_long_double_b, adder_long_double_a,
	adder_long_double_b, divider_long_double_a, divider_long_double_b,
	subtractor_long_double_a, subtractor_long_double_b,
	convertor_from_long_double_to_signed_16_operand;

FIG._9B1

```

reg      zero_substractor_float_run, convertor_from_float_to_long_double_run,
        convertor_from_double_to_long_double_run, multiplier_long_double_run,
        adder_long_double_run, divider_long_double_run, subtractor_long_double_run,
        convertor_from_long_double_to_signed_16_run, ready_func;
reg [4:0] state;
reg [15:0] result_func, _8_16;
reg [31:0] zero_substractor_float_operand, convertor_from_float_to_long_double_operand, _1_32;
reg [63:0] convertor_from_double_to_long_double_operand;
reg [79:0] multiplier_long_double_a, multiplier_long_double_b, adder_long_double_a,
           adder_long_double_b, divider_long_double_a, divider_long_double_b,
           subtractor_long_double_a, subtractor_long_double_b,
           convertor_from_long_double_to_signed_16_operand, _2_80, _3_80, _4_80, _5_80,
           _6_80, _7_80;

always @(posedge clock)
begin
    if (reset)
        state = 0;
    else
        begin
            case (state)
                0: begin
                    if (run_func)
                        begin
                            ready_func = 0;
                            zero_substractor_float_operand = param_func_a;
                            zero_substractor_float_run = 1;
                            state = 1;
                        end
                end
                1: begin
                    zero_substractor_float_run = 0;
                    _1_32 = zero_substractor_float_result;
                    if (zero_substractor_float_ready)
                        state = 2;
                end
                2: begin
                    convertor_from_float_to_long_double_operand = _1_32;
                    convertor_from_float_to_long_double_run = 1;
                    state = 3;
                end
                3: begin
                    convertor_from_float_to_long_double_run = 0;
                    _2_80 = convertor_from_float_to_long_double_result;
                    if (convertor_from_float_to_long_double_ready)
                        state = 4;
                end
            endcase
        end
    end
end

```

FIG._9B2

```
4: begin
    convertor_from_double_to_long_double_operand = param_func_b;
    convertor_from_double_to_long_double_run = 1;
    state = 5;
end
5: begin
    convertor_from_double_to_long_double_run = 0;
    _3_80 = convertor_from_double_to_long_double_result;
    if (convertor_from_double_to_long_double_ready)
        state = 6;
end
6: begin
    multiplier_long_double_a = _3_80;
    multiplier_long_double_b = param_func_c;
    multiplier_long_double_run = 1;
    state = 7;
end
7: begin
    multiplier_long_double_run = 0;
    _4_80 = multiplier_long_double_result;
    if (multiplier_long_double_ready)
        state = 8;
end
8: begin
    adder_long_double_a = _2_80;
    adder_long_double_b = _4_80;
    adder_long_double_run = 1;
    state = 9;
end
9: begin
    adder_long_double_run = 0;
    _5_80 = adder_long_double_result;
    if (adder_long_double_ready)
        state = 10;
end
10: begin
    divider_long_double_a = 80'h00000000000803040;
    divider_long_double_b = param_func_c;
    divider_long_double_run = 1;
    state = 11;
end
11: begin
    divider_long_double_run = 0;
    _6_80 = divider_long_double_result;
    if (divider_long_double_ready)
        state = 12;
end
```

FIG._9B3

```
12: begin
    substractor_long_double_a = _5_80;
    substractor_long_double_b = _6_80;
    substractor_long_double_run = 1;
    state = 13;
end
13: begin
    substractor_long_double_run = 0;
    _7_80 = substractor_long_double_result;
    if (substractor_long_double_ready)
        state = 14;
end
14: begin
    convertor_from_long_double_to_signed_16_operand = _7_80;
    convertor_from_long_double_to_signed_16_run = 1;
    state = 15;
end
15: begin
    convertor_from_long_double_to_signed_16_run = 0;
    _8_16 = convertor_from_long_double_to_signed_16_result;
    if (convertor_from_long_double_to_signed_16_ready)
        state = 16;
end
16: begin
    result_func = _8_16;
    ready_func = 1;
    state = 0;
end
default: ;
endcase
end
end
```

endmodule

FIG._9B4

```
typedef struct
{
    int real;
    int image;
}
Complex;

Complex add (Complex a, Complex b)
{
    Complex c;
    c.real = a.real + b.real;
    c.image = a.image + b.image;
    return c;
}

Complex x = { 1, 2 }, y = { 3, 4 }, z;

void main ()
{
    z = add (x, add (x, y));
}
```

FIG._ 10A

```

`define _add_a 4'h1
`define _add_b 4'h3
`define _3_add_c 4'h5
`define _x      4'h7
`define _y      4'h9
`define _z      4'hB

module Complex (clock, reset, a, d, o, we, result_add, param_add_a,
                param_add_b, run_add, ready_add, run_main, ready_main);
    input      clock, reset, run_add, run_main;
    input [15:0] o;
    input [31:0] param_add_a, param_add_b;
    output     we, ready_add, ready_main;
    output [ 3:0] a;
    output [15:0] d;
    output [31:0] result_add;

    reg      we, ready_add, ready_main;
    reg [ 3:0] a;
    reg [ 4:0] state, return_state_add;
    reg [15:0] d, _1_16, _2_16, _3_16, _4_16, _5_16, _6_16;
    reg [31:0] result_add, _7_32, _8_32, _9_32, _10_32;

    parameter _add = 1;

    always @ (posedge clock)
    begin
        if (reset)
            begin
                we = 0;
                state = 0;
            end
        else
            begin
                case (state)
                    0: begin
                        if (run_add)
                            begin
                                ready_add = 0;
                                return_state_add = 0;
                                a = `add_a;
                                d = param_add_a [31:16];
                                we = 1;
                                state = 2;
                            end
                        else if (run_main)
                            begin
                                ready_main = 0;
                                a = `x;
                                state = 14;
                            end
                end
            end
    end

```

FIG._ 10B1

```

2: begin
    we = 0;
    a = `_add_a + 4'd1;
    d = param_add_a [15:0];
    we = 1;
    state = 3;
end

3: begin
    we = 0;
    a = `_add_b;
    d = param_add_b [31:16];
    we = 1;
    state = 4;
end

4: begin
    we = 0;
    a = `_add_b + 4'd1;
    d = param_add_b [15:0];
    we = 1;
    state = 5;
end

5: begin
    we = 0;
    state = _add;
end

_add: begin
    a = `_add_a;
    state = 6;
end

6: begin
    _1_16 = o;
    a = `_add_b;
    state = 7;
end

7: begin
    _2_16 = o;
    _3_16 = (_1_16 + _2_16);
    a = `_3_add_c;
    d = _3_16;
    we = 1;
    state = 8;
end

8: begin
    we = 0;
    a = (_add_a + 16'd1);
    state = 9;
end

```

FIG._ 10B2

```

9: begin
    _4_16 = o;
    a = `_add_b + 16'd1);
    state = 10;
end

10: begin
    _5_16 = o;
    _6_16 = (_4_16 + _5_16);
    a = `_3_add_c + 16'd1);
    d = _6_16;
    we = 1;
    state = 11;
end

11: begin
    we = 0;
    a = `_3_add_c;
    state = 12;
end

12: begin
    _7_32 [31:16] = o;
    a = `_3_add_c + 4'd1;
    state = 13;
end

13: begin
    _7_32 [15:0] = o;
    result_add = _7_32;
    ready_add = 1;
    state = return_state_add;
end

14: begin
    _8_32 [31:16] = o;
    a = `_x + 4'd1;
    state = 15;
end

15: begin
    _8_32 [15:0] = o;
    a = `_add_a;
    d = _8_32 [31:16];
    we = 1;
    state = 16;
end

16: begin
    we = 0;
    a = `_add_a + 4'd1;
    d = _8_32 [15:0];
    we = 1;
    state = 17;
end

```

FIG._ 10B3

```

17: begin
    we = 0;
    a = `_x;
    state = 18;
end

18: begin
    _9_32 [31:16] = o;
    a = `_x + 4'd1;
    state = 19;
end

19: begin
    _9_32 [15:0] = o;
    a = `_add_a;
    d = _9_32 [31:16];
    we = 1;
    state = 20;
end

20: begin
    we = 0;
    a = `_add_a + 4'd1;
    d = _9_32 [15:0];
    we = 1;
    state = 21;
end

21: begin
    we = 0;
    a = `_y;
    state = 22;
end

22: begin
    _10_32 [31:16] = o;
    a = `_y + 4'd1;
    state = 23;
end

23: begin
    _10_32 [15:0] = o;
    a = `_add_b;
    d = _10_32 [31:16];
    we = 1;
    state = 24;
end

24: begin
    we = 0;
    a = `_add_b + 4'd1;
    d = _10_32 [15:0];
    we = 1;
    state = 25;
end

```

FIG._ 10B4

```

25: begin
    we = 0;
    return_state_add = 26;
    state = _add;
end

26: begin
    a = `_add_b;
    d = result_add [31:16];
    we = 1;
    state = 27;
end

27: begin
    we = 0;
    a = `_add_b + 4'd1;
    d = result_add [15:0];
    we = 1;
    state = 28;
end

28: begin
    we = 0;
    return_state_add = 29;
    state = _add;
end

29: begin
    a = `z;
    d = result_add [31:16];
    we = 1;
    state = 30;
end

30: begin
    we = 0;
    a = `z + 4'd1;
    d = result_add [15:0];
    we = 1;
    state = 31;
end

31: begin
    we = 0;
    ready_main = 1;
    state = 0;
end

default: ;
endcase
end
end

endmodule

```

```

#ifndef __SYNETRY__
#include <assert.h>
#include <stdio.h>
#include <stdlib.h>
#else
#define NULL ((NODE *) 0)
#define assert(a)
#endif
#define MAX_NODES 10
struct _Node
{
    struct _Node * pLeft;
    struct _Node * pRight;
    int          nKey;
    int          nValue;
};
typedef struct _Node NODE;
static NODE Nodes [MAX_NODES];
static int nNodes;
NODE * pTree;
void Initialize (void)
{
    nNodes = 0;
    pTree = NULL;
}
static NODE * NewNode (int nKey, int nValue)
{
    assert (nNodes >= 0 && nNodes <= MAX_NODES);
    if (nNodes == MAX_NODES)
        return NULL;
    Nodes [nNodes].pLeft = NULL;
    Nodes [nNodes].pRight = NULL;
    Nodes [nNodes].nKey  = nKey;
    Nodes [nNodes].nValue = nValue;
    return & Nodes [nNodes++];
}

NODE * FindNode (int nKey)
{
    NODE * p;
    p = pTree;
    while (p != NULL)
    {
        if (p -> nKey < nKey)
            p = p -> pLeft;
        else if (p -> nKey > nKey)
            p = p -> pRight;
        else
            return p;
    }
    return NULL;
}
int FindValue (int nKey)
{
    NODE * p;
    return (p = FindNode (nKey)) == NULL ? -1 : p -> nValue;
}

```

FIG._ 11A1

```

NODE * FindOrAddNode (nKey, nValue)
int nKey;
int nValue;
{ NODE ** p;
  p = & pTree;
  while (*p != NULL)
  {
    if ((*p) -> nKey < nKey)
      p = & (*p) -> pLeft;
    else if ((*p) -> nKey > nKey)
      p = & (*p) -> pRight;
    else
      return (*p);
  }
  return *p = NewNode (nKey, nValue);
}
int FindOrAddValue (nKey, nValue)
int nKey;
int nValue;
{ NODE * p = FindOrAddNode (nKey, nValue);
  return p == NULL ? -1 : p -> nValue;
}
#ifndef __SYNTRY__
void PrintTree (int nLevel, NODE * p)
{ if (p == NULL)
  return;
  PrintTree (nLevel + 1, p -> pLeft);
  printf ("%*s%d [%d]\n", nLevel * 4, "", p -> nKey, p -> nValue);
  PrintTree (nLevel + 1, p -> pRight);
}

void main ()
{ int anKeys [20]
  = { 12, 4, 7, 2, 18, 24, 0, 5, 14, 1, 43, 6, 19, 21, 26, 11, 37, 8, 4, 9};
  int i;

  Initialize ();
  for (i = 0; i < 20; i++)
    FindOrAddValue (anKeys [i], i);
  for (i = 0; i < 20; i++)
    printf ("%d: %d\n", i, FindValue (i));
  printf ("\nTree:\n");
  PrintTree (0, pTree);
}
#endif

```

FIG._ 11A2

```

`define _Nodes` 6'h1
`define _pTree 6'h29

module Tree ( clock, reset, a, d, o, we, result_FindNode, result_FindValue, result_FindOrAddNode,
               result_FindOrAddValue, param_FindNode_nKey, param_FindValue_nKey,
               param_FindOrAddNode_nKey, param_FindOrAddNode_nValue,
               param_FindOrAddValue_nKey, param_FindOrAddValue_nValue,
               run_Initialize, ready_Initialize, run_FindNode, ready_FindNode,
               run_FindValue, ready_FindValue, run_FindOrAddNode,
               ready_FindOrAddNode, run_FindOrAddValue, ready_FindOrAddValue );
  input   clock, reset, run_Initialize, run_FindNode, run_FindValue, run_FindOrAddNode,
          run_FindOrAddValue;
  input [15:0] o, param_FindNode_nKey, param_FindValue_nKey, param_FindOrAddNode_nKey,
              param_FindOrAddNode_nValue, param_FindOrAddValue_nKey,
              param_FindOrAddValue_nValue;
  output  we, ready_Initialize, ready_FindNode, ready_FindValue, ready_FindOrAddNode,
          ready_FindOrAddValue;
  output [5:0] a, result_FindNode, result_FindOrAddNode, d, result_FindValue, result_FindOrAddValue;
  reg      we, ready_Initialize, ready_FindNode, ready_FindValue, ready_FindOrAddNode,
          ready_FindOrAddValue;
  reg [5:0] a, result_FindNode, result_FindOrAddNode, d, result_FindValue, result_FindOrAddValue,
            state, result_NewNode, _7_FindNode_p, _10_FindValue_p, _13_FindOrAddNode_p,
            _17_FindOrAddValue_p, return_state_NewNode, return_state_FindNode,
            return_state_FindOrAddNode, _1_6, _2_6, _3_6, _4_6, _5_6, _6_6, _7_6, _8_6, _9_6,
            _10_6, _12_6, _13_6, _14_6, _18_6, _22_6, _23_6, _24_6, _27_6, _28_6, _29_6,
            _33_6, _34_6, _38_6, _39_6, _40_6;
  reg [15:0] _nNodes, _NewNode_nKey, _NewNode_nValue, _FindNode_nKey,
             _FindOrAddNode_nKey, _FindOrAddNode_nValue, _30_16, _35_16, _11_16, _15_16,
             _19_16, _25_16, _26_16, _41_16, _42_16;
  reg [16:0] _16_17, _17_17, _20_17, _21_17, _31_17, _32_17, _36_17, _37_17;

  parameter _NewNode      = 1,
            _FindNode     = 5,
            _FindOrAddNode = 14;

always @(posedge clock)
begin
  if (reset)
    begin
      we = 0;
      state = 0;
    end
end

```

FIG._ 11B1

```

else
begin
    case (state)
    0: begin
        if (run_Initialize)
        begin
            ready_Initialize = 0;
            _nNodes = 16'd0;
            _1_6 = 16'd0;
            a = `pTree;
            d [15:10] = _1_6;
            we = 1;
            state = 23;
        end
    else if (run_FindNode)
    begin
        ready_FindNode = 0;
        return_state_FindNode = 0;
        _FindNode_nKey = param_FindNode_nKey;
        state = _FindNode;
    end
    else if (run_FindValue)
    begin
        ready_FindValue = 0;
        _FindNode_nKey = param_FindValue_nKey;
        return_state_FindNode = 33;
        state = _FindNode;
    end
    else if (run_FindOrAddNode)
    begin
        ready_FindOrAddNode = 0;
        return_state_FindOrAddNode = 0;
        _FindOrAddNode_nKey = param_FindOrAddNode_nKey;
        _FindOrAddNode_nValue = param_FindOrAddNode_nValue;
        state = _FindOrAddNode;
    end
    else if (run_FindOrAddValue)
    begin
        ready_FindOrAddValue = 0;
        _FindOrAddNode_nKey = param_FindOrAddValue_nKey;
        _FindOrAddNode_nValue = param_FindOrAddValue_nValue;
        return_state_FindOrAddNode = 48;
        state = _FindOrAddNode;
    end
end
23: begin
    we = 0;
    ready_Initialize = 1;
    state = 0;
end
_NewNode: state = (_nNodes == 16'd10) ? 2 : 3;

```

FIG._ 11B2

```

2: begin
    _2_6 = 16'd0;
    result_NewNode = _2_6;
    state = 4;
end

3: begin
    _3_6 = 16'd0;
    _4_6 = (_nNodes << 2'd2);
    _5_6 = _3_6;
    a = (^_Nodes + _4_6);
    d [15:10] = _5_6;
    we = 1;
    state = 24;
end

24: begin
    we = 0;
    _6_6 = 16'd0;
    _7_6 = (_nNodes << 2'd2);
    _8_6 = _6_6;
    a = ((^_Nodes + _7_6) + 6'd1);
    d [15:10] = _8_6;
    we = 1;
    state = 25;
end

25: begin
    we = 0;
    _9_6 = (_nNodes << 2'd2);
    a = ((^_Nodes + _9_6) + 6'd2);
    d = _NewNode_nKey;
    we = 1;
    state = 26;
end

26: begin
    we = 0;
    _10_6 = (_nNodes << 2'd2);
    a = ((^_Nodes + _10_6) + 6'd3);
    d = _NewNode_nValue;
    we = 1;
    state = 27;
end

27: begin
    we = 0;
    _11_16 = _nNodes;
    _nNodes = (_11_16 + 16'd1);
    _12_6 = (_11_16 << 2'd2);
    result_NewNode = (^_Nodes + _12_6);
    state = 4;
end

```

FIG._ 11B3

```

4: state = return_state_NewNode;

FindNode: begin
    a = `_pTree;
    state = 28;
end

28: begin
    _13_6 = o [15:10];
    _7_FindNode_p = _13_6;
    state = 6;
end

6: begin
    _14_6 = 16'd0;
    state = (_7_FindNode_p != _14_6) ? 7 : 12;
end

7: begin
    a = (_7_FindNode_p + 6'd2);
    state = 29;
end

29: begin
    _15_16 = o;
    _16_17 = { ~_15_16 [15], _15_16 };
    _17_17 = { ~_FindNode_nKey [15], _FindNode_nKey };
    state = (_16_17 < _17_17) ? 8 : 9;
end

8: begin
    a = _7_FindNode_p;
    state = 30;
end

30: begin
    _18_6 = o [15:10];
    _7_FindNode_p = _18_6;
    state = 6;
end

9: begin
    a = (_7_FindNode_p + 6'd2);
    state = 31;
end

31: begin
    _19_16 = o;
    _20_17 = { ~_19_16 [15], _19_16 };
    _21_17 = { ~_FindNode_nKey [15], _FindNode_nKey };
    state = (_20_17 > _21_17) ? 10 : 11;
end

10: begin
    a = (_7_FindNode_p + 6'd1);
    state = 32;
end

```

FIG._ 11B4

```
32: begin
    _22_6 = 0 {15:10};
    _7_FindNode_p = _22_6;
    state = 6;
end

11: begin
    result_FindNode = _7_FindNode_p;
    state = 13;
end

12: begin
    _23_6 = 16'd0;
    result_FindNode = _23_6;
    state = 13;
end

13: begin
    ready_FindNode = 1;
    state = return_state_FindNode;
end

33: begin
    _10_FindValue_p = result_FindNode;
    _24_6 = 16'd0;
    state = (result_FindNode == _24_6) ? 34 : 35;
end

34: begin
    _25_16 = -16'd1;
    state = 36;
end

35: begin
    a := (_10_FindValue_p + 6'd3);
    state = 37;
end

37: begin
    _26_16 = 0;
    _25_16 = _26_16;
    state = 36;
end

36: begin
    result_FindValue = _25_16;
    ready_FindValue = 1;
    state = 0;
end
```

FIG._ 11B5

```

_FindOrAddNode: begin
    _13_FindOrAddNode_p = `pTree;
    state = 15;
end

15: begin
    a = _13_FindOrAddNode_p;
    state = 38;
end

38: begin
    _27_6 = o [15:10];
    _28_6 = 16'd0;
    state = (_27_6 != _28_6) ? 16 : 21;
end

16: begin
    a = _13_FindOrAddNode_p;
    state = 39;
end

39: begin
    _29_6 = o [15:10];
    a = (_29_6 + 6'd2);
    state = 40;
end

40: begin
    _30_16 = o;
    _31_17 = { ~ _30_16 [15], _30_16 };
    _32_17 = { ~ _FindOrAddNode_nKey [15], _FindOrAddNode_nKey };
    state = (_31_17 < _32_17) ? 17 : 18;
end

17: begin
    a = _13_FindOrAddNode_p;
    state = 41;
end

41: begin
    _33_6 = o [15:10];
    _13_FindOrAddNode_p = _33_6;
    state = 15;
end

18: begin
    a = _13_FindOrAddNode_p;
    state = 42;
end

42: begin
    _34_6 = o [15:10];
    a = (_34_6 + 6'd2);
    state = 43;
end

```

FIG._ 11B6

TOP SECRET//COMINT

```
43: begin
    _35_16 = 0;
    _36_17 = { ~ _35_16 [15], _35_16 };
    _37_17 = { ~ _FindOrAddNode_nKey [15], _FindOrAddNode_nKey };
    state = (_36_17 > _37_17) ? 19 : 20;
end

19: begin
    a = _13_FindOrAddNode_p;
    state = 44;
end

44: begin
    _38_6 = o [15:10];
    _13_FindOrAddNode_p = (_38_6 + 6'd1);
    state = 15;
end

20: begin
    a = _13_FindOrAddNode_p;
    state = 45;
end

45: begin
    _39_6 = o [15:10];
    result_FindOrAddNode = _39_6;
    state = 22;
end

21: begin
    _NewNode_nKey = _FindOrAddNode_nKey;
    _NewNode_nValue = _FindOrAddNode_nValue;
    return_state_NewNode = 46;
    state = _NewNode;
end

46: begin
    a = _13_FindOrAddNode_p;
    d [15:10] = result_NewNode;
    we = 1;
    state = 47;
end

47: begin
    we = 0;
    result_FindOrAddNode = result_NewNode;
    state = 22;
end
```

FIG._ 11B7

TOP SECRET//COMINT

```
22: begin
    ready_FindOrAddNode = 1;
    state = return_state_FindOrAddNode;
end

48: begin
    _17_FindOrAddValue_p = result_FindOrAddNode;
    _40_6 = 16'd0;
    state = (_17_FindOrAddValue_p == _40_6) ? 49 : 50;
end

49: begin
    _41_16 = -16'd1;
    state = 51;
end

50: begin
    a = (_17_FindOrAddValue_p + 6'd3);
    state = 52;
end

52: begin
    _42_16 = 0;
    _41_16 = _42_16;
    state = 51;
end

51: begin
    result_FindOrAddValue = _41_16;
    ready_FindOrAddValue = 1;
    state = 0;
end

default: ;
endcase
end
end
```

endmodule

FIG._ 11B8

```
#include <stdio.h>
int event_occurred = 0;
#pragma synchronous on_event

void on_event()
{
    event_occurred = 1;
}

void main()
{
    int a, b, c;
    scanf ("%d %d", &a, &b);
    c = event_occurred ? a + b : a - b;
    printf ("%d\n", c);
}
```

FIG._ 12A

TOP SECRET SOURCE CODE

```
module Event_sy (clock,reset,scanf_0_1_line_16_a,scanf_0_2_line_16_b,printf_1_1_line_20_c,
                 run_on_event,run_main);
    input      clock, reset, run_on_event, run_main;
    input [15:0] scanf_0_1_line_16_a, scanf_0_2_line_16_b;
    output [15:0] printf_1_1_line_20_c;
    reg   [15:0] printf_1_1_line_20_c, _event_occurred, _108_main_a, _108_main_b, _108_main_c;

    always @(posedge clock)
    begin
        if (run_on_event)
            _event_occurred = 16'd1;
        if (reset)
            _event_occurred = 16'd0;
    end

    always @(posedge clock)
    begin
        if (run_main)
        begin
            _108_main_a = scanf_0_1_line_16_a;
            _108_main_b = scanf_0_2_line_16_b;
            _108_main_c = (_event_occurred ? (_108_main_a + _108_main_b) :
                           (_108_main_a - _108_main_b));
            printf_1_1_line_20_c = _108_main_c;
        end
    end
endmodule
```

FIG._ 12B

```
#include <stdio.h>

int event_occurred = 0;
#pragma asynchronous on_event
void on_event ()
{
    event_occurred = 1;
}

void main ()
{
    int a, b, c;
    scanf ("%d %d", &a, &b);
    c = event_occurred ? a + b : a - b;
    printf ("%d\n", c);
}
```

FIG._ 13A

TOP SECRET//COMINT

```
module Event_as(clock,reset,scanf_0_1_line_16_a,scanf_0_2_line_16_b,printf_1_1_line_20_c,
                run_on_event,run_main);
    input      clock, reset, run_on_event, run_main;
    input [15:0] scanf_0_1_line_16_a, scanf_0_2_line_16_b;
    output [15:0] printf_1_1_line_20_c;
    reg   [15:0] printf_1_1_line_20_c, _event_occurred, _108_main_a, _108_main_b, _108_main_c;

    always @(posedge run_on_event)
    begin
        if (reset)
            _event_occurred = 16'd0;
        else
            _event_occurred = 16'd1;
    end

    always @(posedge clock)
    begin
        if (run_main)
        begin
            _108_main_a = scanf_0_1_line_16_a;
            _108_main_b = scanf_0_2_line_16_b;
            _108_main_c = (_event_occurred ? (_108_main_a + _108_main_b) :
                                (_108_main_a - _108_main_b));
            printf_1_1_line_20_c = _108_main_c;
        end
    end
endmodule
```

FIG._ 13B

+

```

int func1 (unsigned n)
{
    unsigned i, result = 0;
    for (i = 0; i <= n; i++)
        result += i;
    return result;
}

int func2 (unsigned n)
{
    unsigned i, result = 0;
    for (i = 0; i <= n; i++)
        result += i;
    return result;
}

```

FIG._ 14A

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```

module Sum (clock, reset, result_func1, param_func1_n, run_func1, ready_func1, result_func2,
            param_func2_n, run_func2, ready_func2);
    input      clock, reset, run_func1, run_func2;
    input [15:0] param_func1_n, param_func2_n;
    output     ready_func1, ready_func2;
    output [15:0] result_func1, result_func2;
    reg        ready_func1, ready_func2;
    reg      [1:0] state1, state2;
    reg      [15:0] result_func1, result_func2, s_2_func1_i, s_2_func1_result, s_2_func2_i,
                  s_2_func2_result;
    always @(posedge clock)
        begin
            if (reset)
                state1 = 0;
            else
                begin
                    case (state1)
                        0: begin
                            if (run_func1)
                                begin
                                    ready_func1 = 0;
                                    s_2_func1_result = 16'd0;
                                    s_2_func1_i = 16'd0;
                                    state1 = 1;
                                end
                            end
                        end
                end

```

FIG._ 14B1

```

1: state1 = (s_2_func1_i <= param_func1_n) ? 2 : 3;

2: begin
    s_2_func1_result = (s_2_func1_result + s_2_func1_i);
    s_2_func1_i = (s_2_func1_i + 16'd1);
    state1 = 1;
end

3: begin
    result_func1 = s_2_func1_result;
    ready_func1 = 1;
    state1 = 0;
end
endcase
end
end

always @(posedge clock)
begin
    if (reset)
        state2 = 0;
    else
begin
    case (state2)
0: begin
        if (run_func2)
begin
            ready_func2 = 0;
            s_2_func2_result = 16'd0;
            s_2_func2_i = 16'd0;
            state2 = 1;
end
end
end

1: state2 = (s_2_func2_i <= param_func2_n) ? 2 : 3;

2: begin
    s_2_func2_result = (s_2_func2_result + s_2_func2_i);
    s_2_func2_i = (s_2_func2_i + 16'd1);
    state2 = 1;
end

3: begin
    result_func2 = s_2_func2_result;
    ready_func2 = 1;
    state2 = 0;
end
endcase
end
end

endmodule

```

FIG.- 14B2

```
#include <stdio.h>
#include <stdarg.h>
/* Returns the average of a variable list of integers. */

static int average (int first, ...)
{
    int count = 0, sum = 0, i = first;
    va_list marker;

    va_start (marker, first); /* Initialize variable arguments. */

    while (i != -1)
    {
        sum += i;
        count++;
        i = va_arg (marker, int);
    }

    va_end (marker); /* Reset variable arguments. */

    return sum ? (sum / count) : 0;
}

void main ()
{
    /* Call with 3 integers (-1 is used as terminator). */
    printf ("Average is: %d\n", average (2, 3, 4, -1));

    /* Call with 4 integers. */
    printf ("Average is: %d\n", average (5, 7, 9, 11, -1));

    /* Call with just -1 terminator. */
    printf ("Average is: %d\n", average (-1));
}
```

FIG._ 15A

```

`define _average_first 5'h1

module udivmod16 (a, b, div, mod);
    input [15:0] a, b;
    output [15:0] div, mod;
    reg [15:0] div, mod, pa0, pa1, pa2, pa3, pa4, pa5, pa6, pa7, pa8, pa9, pa10,
                pa11, pa12, pa13, pa14, pa15, pa16, shb0;
    reg [16:0] shb1;
    reg [17:0] shb2;
    reg [18:0] shb3;
    reg [19:0] shb4;
    reg [20:0] shb5;
    reg [21:0] shb6;
    reg [22:0] shb7;
    reg [23:0] shb8;
    reg [24:0] shb9;
    reg [25:0] shb10;
    reg [26:0] shb11;
    reg [27:0] shb12;
    reg [28:0] shb13;
    reg [29:0] shb14;
    reg [30:0] shb15;

    always @(a or b)
    begin
        pa0 = a;
        shb15 = b << 15;
        div [15] = pa0 >= shb15;
        pa1 = div [15] ? pa0 - shb15 : pa0;
        shb14 = b << 14;
        div [14] = pa1 >= shb14;
        pa2 = div [14] ? pa1 - shb14 : pa1;
        shb13 = b << 13;
        div [13] = pa2 >= shb13;
        pa3 = div [13] ? pa2 - shb13 : pa2;
        shb12 = b << 12;
        div [12] = pa3 >= shb12;
        pa4 = div [12] ? pa3 - shb12 : pa3;
        shb11 = b << 11;
        div [11] = pa4 >= shb11;
        pa5 = div [11] ? pa4 - shb11 : pa4;
        shb10 = b << 10;
        div [10] = pa5 >= shb10;
        pa6 = div [10] ? pa5 - shb10 : pa5;
        shb9 = b << 9;
        div [9] = pa6 >= shb9;
        pa7 = div [9] ? pa6 - shb9 : pa6;
    end
endmodule

```

```

shb8    = b << 8;
div [ 8] = pa7 >= shb8;
pa8     = div [8] ? pa7 - shb8 : pa7;
shb7    = b << 7;
div [ 7] = pa8 >= shb7;
pa9     = div [7] ? pa8 - shb7 : pa8;
shb6    = b << 6;
div [ 6] = pa9 >= shb6;
pa10   = div [6] ? pa9 - shb6 : pa9;
shb5    = b << 5;
div [ 5] = pa10 >= shb5;
pa11   = div [5] ? pa10 - shb5 : pa10;
shb4    = b << 4;
div [ 4] = pa11 >= shb4;
pa12   = div [4] ? pa11 - shb4 : pa11;
shb3    = b << 3;
div [ 3] = pa12 >= shb3;
pa13   = div [3] ? pa12 - shb3 : pa12;
shb2    = b << 2;
div [ 2] = pa13 >= shb2;
pa14   = div [2] ? pa13 - shb2 : pa13;
shb1    = b << 1;
div [ 1] = pa14 >= shb1;
pa15   = div [1] ? pa14 - shb1 : pa14;
shb0    = b << 0;
div [ 0] = pa15 >= shb0;
pa16   = div [0] ? pa15 - shb0 : pa15;
mod = pa16;
end
endmodule

module sdivmod16 (a, b, div, mod);
  input [15:0] a, b;
  output [15:0] div, mod;
  wire [15:0] ua = a [15] ? - a : a;
  wire [15:0] ub = b [15] ? - b : b;
  wire [15:0] udiv, umod;
  udivmod16 udivmod (ua, ub, udiv, umod);
  wire [15:0] div = (a [15] != b [15]) ? - udiv : udiv;
  wire [15:0] mod = a [15] ? - umod : umod;
endmodule

```

FIG._ 15B2

```

module RAM32X1 (O, D, WE, A4, A3, A2, A1, A0)
    /* synthesis black_box xc_alias="RAM" */;
    output      O;
    input       D, WE, A4, A3, A2, A1, A0;
    reg [31:0]   d;
    wire [4:0]   A = { A4, A3, A2, A1, A0 };
    assign O = d [A];
    always @(A or D or WE)
        if (WE)
            d [A] = D;
endmodule

module RAM32x1 (a, d, o, we);
    input           d, we;
    input [4:0]     a;
    output          o;
    RAM32X1 RAM32X1 (o, d, we, a [4], a [3], a [2], a [1], a [0]);
endmodule

module RAM32x16 (a, d, o, we);
    input          we;
    input [4:0]    a;
    input [15:0]   d;
    output [15:0]  o;
    RAM32x1 U0 (a, d [0], o [0], we);
    RAM32x1 U1 (a, d [1], o [1], we);
    RAM32x1 U2 (a, d [2], o [2], we);
    RAM32x1 U3 (a, d [3], o [3], we);
    RAM32x1 U4 (a, d [4], o [4], we);
    RAM32x1 U5 (a, d [5], o [5], we);
    RAM32x1 U6 (a, d [6], o [6], we);
    RAM32x1 U7 (a, d [7], o [7], we);
    RAM32x1 U8 (a, d [8], o [8], we);
    RAM32x1 U9 (a, d [9], o [9], we);
    RAM32x1 U10 (a, d [10], o [10], we);
    RAM32x1 U11 (a, d [11], o [11], we);
    RAM32x1 U12 (a, d [12], o [12], we);
    RAM32x1 U13 (a, d [13], o [13], we);
    RAM32x1 U14 (a, d [14], o [14], we);
    RAM32x1 U15 (a, d [15], o [15], we);
endmodule

module RAM18x16 (a, d, o, we);
    input          we;
    input [4:0]    a;
    input [15:0]   d;
    output [15:0]  o;
    RAM32x16 U (a, d, o, we);
endmodule

```

FIG._ 15B3

```

module StdArg (clock, reset, printf_1_1_line_42, printf_2_1_line_45, printf_3_1_line_48,
               run_main, ready_main );
  input      clock, reset, run_main;
  output     ready_main;
  output [15:0] printf_1_1_line_42, printf_2_1_line_45, printf_3_1_line_48
  reg        ready_main, we;
  reg [4:0]   state, a, return_state_average;
  reg [15:0]  printf_1_1_line_42, printf_2_1_line_45, printf_3_1_line_48, divmod_a, divmod_b,
               d, result_average, _108_average_count, _108_average_sum, _108_average_i,
               _108_average_marker, _1_16, _2_16, _3_16, _4_16, _5_16, _6_16, _7_16, _8_16,
               _9_16, _10_16, _11_16, _12_16, _13_16, _14_16;
  wire [15:0] div_result, o;
  sdivmod16 sdivmod (divmod_a, divmod_b, div_result, );

  RAM18x16 m (a, d, o, we);
  parameter _average = 1;

  always @(posedge clock)
  begin
    if (reset)
      begin
        we = 0;
        state = 0;
      end
    else
      begin
        case (state)
          0: begin
            if (run_main)
              begin
                ready_main = 0;
                _5_16 = 16'd2;
                a = `_average_first;
                d = _5_16;
                we = 1;
                state = 11;
              end
            end
            _average: begin
              _108_average_count = 16'd0;
              _108_average_sum = 16'd0;
              a = `_average_first;
              state = 5;
            end
            5: begin
              _1_16 = o;
              _108_average_i = _1_16;
              _108_average_marker = (_average_first + 16'd1);
              state = 2;
            end
            2: state = (_108_average_i != -16'd1) ? 3 : 4;
          end
        endcase
      end
  end
endmodule

```

```
3: begin
    _108_average_sum = (_108_average_sum + _108_average_i);
    _108_average_count = (_108_average_count + 16'd1);
    _108_average_marker = (_108_average_marker + 16'd1);
    a = (_108_average_marker - 16'd1);
    state = 6;
end

6: begin
    _2_16 = o;
    _108_average_i = _2_16;
    state = 2;
end

4: begin
    _108_average_marker = 16'd0;
    state = _108_average_sum ? 7 : 8;
end

7: begin
    divmod_a = _108_average_sum;
    divmod_b = _108_average_count;
    state = 10;
end

10: begin
    _4_16 = div_result;
    _3_16 = _4_16;
    state = 9;
end

8: begin
    _3_16 = 16'd0;
    state = 9;
end

9: begin
    result_average = _3_16;
    state = return_state_average;
end

11: begin
    we = 0;
    _6_16 = 16'd3;
    a = (_average_first + 16'd1);
    d = _6_16;
    we = 1;
    state = 12;
end
```

FIG._ 15B5

```

12: begin
    we = 0;
    _7_16 = 16'd4;
    a = (_average_first + 16'd2);
    d = _7_16;
    we = 1;
    state = 13;
end

13: begin
    we = 0;
    _8_16 = -16'd1;
    a = (_average_first + 16'd3);
    d = _8_16;
    we = 1;
    state = 14;
end

14: begin
    we = 0;
    return_state_average = 15;
    state = _average;
end

15: begin
    printf_1_1_line_42 = result_average;
    // User Verilog code
    $write ("Average is: %d\n", printf_1_1_line_42);
    // End of user Verilog code
    _9_16 = 16'd5;
    a = `_average_first;
    d = _9_16;
    we = 1;
    state = 16;
end

16: begin
    we = 0;
    _10_16 = 16'd7;
    a = (_average_first + 16'd1);
    d = _10_16;
    we = 1;
    state = 17;
end

17: begin
    we = 0;
    _11_16 = 16'd9;
    a = (_average_first + 16'd2);
    d = _11_16;
    we = 1;
    state = 18;
end

```

FIG._ 15B6

```

18: begin
    we = 0;
    _12_16 = 16'd11;
    a = (_average_first + 16'd3);
    d = _12_16;
    we = 1;
    state = 19;
end

19: begin
    we = 0;
    _13_16 = -16'd1;
    a = (_average_first + 16'd4);
    d = _13_16;
    we = 1;
    state = 20;
end

20: begin
    we = 0;
    return_state_average = 21;
    state = _average;
end

21: begin
    printf_2_1_line_45 = result_average;
    // User Verilog code
    $write ("Average is: %d\n", printf_2_1_line_45);
    // End of user Verilog code
    _14_16 = -16'd1;
    a = `_average_first;
    d = _14_16;
    we = 1;
    state = 22;
end

22: begin
    we = 0;
    return_state_average = 23;
    state = _average;
end

23: begin
    printf_3_1_line_48 = result_average;
    // User Verilog code
    $write ("Average is: %d\n", printf_3_1_line_48);
    // End of user Verilog code
    ready_main = 1;
    state = 0;
end

    default: ;
endcase
end
end
endmodule

```

FIG._15B7

```
#include <stdio.h>

static void MoveRing (int nRings, int Tower1, int Tower2, int Tower3)
{
    if (nRings == 0)
        return;

    MoveRing (nRings - 1, Tower1, Tower3, Tower2);
    printf ("%d -> %d\n", Tower1, Tower2);
    MoveRing (nRings - 1, Tower3, Tower2, Tower1);
}

void Hanoi (int nRings)
{
    MoveRing (nRings, 1, 2, 3);
}

#ifndef __SYNTRY__
void main (void)
{
    printf ("Five rings Hanoi Towers\n");
    Hanoi (5);
}
#endif
```

FIG._ 16A

```

`define recursion_stack 8'h1
module Hanoi (clock, reset, a, d, o, we, printf_1_1_line_22_Tower1, printf_1_2_line_22_Tower2,
              param_Hanoi_nRings, run_Hanoi, ready_Hanoi );
    input      clock, reset, run_Hanoi;
    input [ 7:0] o, param_Hanoi_nRings;
    output     we, ready_Hanoi;
    output [ 7:0] a, d, printf_1_1_line_22_Tower1, printf_1_2_line_22_Tower2;
    reg        we, ready_Hanoi;
    reg [ 4:0] state, return_state_MoveRing;
    reg [ 7:0] a, d, printf_1_1_line_22_Tower1, printf_1_2_line_22_Tower2, recursion_stack_pointer,
               _MoveRing_nRings, _MoveRing_Tower1, _MoveRing_Tower2, _MoveRing_Tower3,
               _1_8, _2_8, _3_8, _4_8, _5_8, _6_8, _7_8, _8_8, _9_8, _10_8, _11_8, _12_8;
    parameter _MoveRing = 1;

    always @(posedge clock)
    begin
        if (reset)
            begin
                we = 0;
                recursion_stack_pointer = `recursion_stack;
                state = 0;
            end
        else
            begin
                case (state)
                    0: begin
                        if (run_Hanoi)
                            begin
                                ready_Hanoi = 0;
                                _MoveRing_nRings = param_Hanoi_nRings;
                                _MoveRing_Tower1 = 8'd1;
                                _MoveRing_Tower2 = 8'd2;
                                _MoveRing_Tower3 = 8'd3;
                                return_state_MoveRing = 26;
                                state = _MoveRing;
                            end
                    end
                    _MoveRing: state = (_MoveRing_nRings == 8'd0) ? 3 : 2;
                    2: begin
                        _1_8 = (_MoveRing_nRings - 8'd1);
                        _2_8 = _MoveRing_Tower1;
                        _3_8 = _MoveRing_Tower3;
                        _4_8 = _MoveRing_Tower2;
                        a = recursion_stack_pointer;
                        d = _MoveRing_nRings;
                        we = 1;
                        state = 4;
                    end
                endcase
            end
    end
endmodule

```

FIG._ 16B1

```
4: begin
    we = 0;
    a = recursion_stack_pointer + 1;
    d = _MoveRing_Tower1;
    we = 1;
    state = 5;
end

5: begin
    we = 0;
    a = recursion_stack_pointer + 2;
    d = _MoveRing_Tower2;
    we = 1;
    state = 6;
end

6: begin
    we = 0;
    a = recursion_stack_pointer + 3;
    d = _MoveRing_Tower3;
    we = 1;
    state = 7;
end

7: begin
    we = 0;
    _9_8 = return_state_MoveRing;
    a = recursion_stack_pointer + 4;
    d = _9_8;
    we = 1;
    state = 8;
end

8: begin
    we = 0;
    recursion_stack_pointer = recursion_stack_pointer + 5;
    _MoveRing_nRings = _1_8;
    _MoveRing_Tower1 = _2_8;
    _MoveRing_Tower2 = _3_8;
    _MoveRing_Tower3 = _4_8;
    return_state_MoveRing = 9;
    state = _MoveRing;
end

9: begin
    recursion_stack_pointer = recursion_stack_pointer - 5;
    a = recursion_stack_pointer;
    state = 10;
end

10: begin
    _MoveRing_nRings = 0;
    a = recursion_stack_pointer + 1;
    state = 11;
end
```

FIG._ 16B2

```
11: begin
    _MoveRing_Tower1 = 0;
    a = recursion_stack_pointer + 2;
    state = 12;
end

12: begin
    _MoveRing_Tower2 = 0;
    a = recursion_stack_pointer + 3;
    state = 13;
end

13: begin
    _MoveRing_Tower3 = 0;
    a = recursion_stack_pointer + 4;
    state = 14;
end

14: begin
    _10_8 = 0;
    return_state_MoveRing = _10_8;
    printf_1_1_line_22_Tower1 = _MoveRing_Tower1;
    printf_1_2_line_22_Tower2 = _MoveRing_Tower2;
    // User Verilog code
    $write ("%d -> %d\n", printf_1_1_line_22_Tower1, printf_1_2_line_22_Tower2);
    // End of user Verilog code
    _5_8 = (_MoveRing_nRings - 8'd1);
    _6_8 = _MoveRing_Tower3;
    _7_8 = _MoveRing_Tower2;
    _8_8 = _MoveRing_Tower1;
    a = recursion_stack_pointer;
    d = _MoveRing_nRings;
    we = 1;
    state = 15;
end

15: begin
    we = 0;
    a = recursion_stack_pointer + 1;
    d = _MoveRing_Tower1;
    we = 1;
    state = 16;
end

16: begin
    we = 0;
    a = recursion_stack_pointer + 2;
    d = _MoveRing_Tower2;
    we = 1;
    state = 17;
end
```

FIG._ 16B3

```
17: begin
    we = 0;
    a = recursion_stack_pointer + 3;
    d = _MoveRing_Tower3;
    we = 1;
    state = 18;
end

18: begin
    we = 0;
    _11_8 = return_state_MoveRing;
    a = recursion_stack_pointer + 4;
    d = _11_8;
    we = 1;
    state = 19;
end

19: begin
    we = 0;
    recursion_stack_pointer = recursion_stack_pointer + 5;
    _MoveRing_nRings = _5_8;
    _MoveRing_Tower1 = _6_8;
    _MoveRing_Tower2 = _7_8;
    _MoveRing_Tower3 = _8_8;
    return_state_MoveRing = 20;
    state = _MoveRing;
end

20: begin
    recursion_stack_pointer = recursion_stack_pointer - 5;
    a = recursion_stack_pointer;
    state = 21;
end

21: begin
    _MoveRing_nRings = o;
    a = recursion_stack_pointer + 1;
    state = 22;
end

22: begin
    _MoveRing_Tower1 = o;
    a = recursion_stack_pointer + 2;
    state = 23;
end

23: begin
    _MoveRing_Tower2 = o;
    a = recursion_stack_pointer + 3;
    state = 24;
end
```

FIG._ 16B4

```
24: begin
    _MoveRing_Tower3 = o;
    a = recursion_stack_pointer + 4;
    state = 25;
end

25: begin
    _12_8 = o;
    return_state_MoveRing = _12_8;
    state = 3;
end

3: state = return_state_MoveRing;

26: begin
    ready_Hanoi = 1;
    state = 0;
end

default: ;
endcase
end
end
endmodule
```

FIG._ 16B5

```
#include <stdio.h>

void f1 ()
{
    printf ("%d\n", 1);
}

void f2 ()
{
    printf ("%d\n", 2);
}

void main (n)
{
    void (* f) ();
    f = n == 1 ? f1 : f2;
    f ();
}
```

FIG._ 17A

OPEN SOURCE DESIGN

```
module PtrFun (clock, reset, printf_1_1_line_19, printf_2_1_line_24, param_main_n, run_f1, ready_f1,
               run_f2, ready_f2, run_main, ready_main);
    input      clock, reset, run_f1, run_f2, run_main;
    input [15:0] param_main_n;
    output     ready_f1, ready_f2, ready_main;
    output [15:0] printf_1_1_line_19, printf_2_1_line_24;
    reg        ready_f1, ready_f2, ready_main;
    reg [1:0]   state, return_state_f1, return_state_f2;
    reg [15:0]  printf_1_1_line_19, printf_2_1_line_24, _110_main_f;
    parameter _f1 = 1, _f2 = 2;

    always @(posedge clock)
    begin
        if (reset)
            begin
                printf_1_1_line_19 = 0;
                printf_2_1_line_24 = 0;
                _110_main_f      = 0;
                ready_f1          = 0;
                return_state_f1   = 0;
                ready_f2          = 0;
                return_state_f2   = 0;
                ready_main        = 0;
                state = 0;
            end
    end
```

FIG._ 17B1

```

else
begin
  case (state)
    0: begin
      if (run_f1)
        begin
          ready_f1 = 0;
          return_state_f1 = 0;
          state = _f1;
        end
      else if (run_f2)
        begin
          ready_f2 = 0;
          return_state_f2 = 0;
          state = _f2;
        end
      else if (run_main)
        begin
          ready_main = 0;
          _110_main_f = ((param_main_n == 16'd1) ? _f1 : _f2);
          state = _110_main_f;
        end
      end
    _f1: begin
      printf_1_1_line_19 = 16'd1;
      // User Verilog code
      $write ("%d\n", printf_1_1_line_19);
      // End of user Verilog code
      ready_f1 = 1;
      state = return_state_f1;
    end
    _f2: begin
      printf_2_1_line_24 = 16'd2;
      // User Verilog code
      $write ("%d\n", printf_2_1_line_24);
      // End of user Verilog code
      ready_f2 = 1;
      state = return_state_f2;
    end
    3: begin
      ready_main = 1;
      state = 0;
    end
    default: ;
  endcase
end
end
endmodule

```

FIG._ 17B2

```
int sum (int array [], int size)
{
    int i, sum = 0;

    for (i = 0; i < size; i++)
        sum += array [i];

    return sum;
}

int main ()
{
    int i;
    int array [10];
    int size = sizeof (array) / sizeof (*array);

    array [0] = 1;
    array [1] = 2;
    array [2] = 3;

    for (i = 3; i < size; i++)
        array [i] = i * 2;

    return sum (array, size);
}
```

FIG._ 18A

```

// Global macro definitions
`define UNIT_MAIN      16'h5000
`define UNIT_SIZE       16
`define ADDRESS_SIZE    16
`define DATA_SIZE        32

// Local macro definitions
`define STATE_SIZE      5
`define WORD_SIZE        32
`define WORD_MEMORY_SIZE 15
`define MEMORY_SIZE      480

// External functions defined in the translated C file
`define _sum            32'h50000001
`define offset_sum       1
`define var_sum          memory [1]
`define state_sum        5'd1
`define _sum_array       32'h50000002
`define offset_sum_array 2
`define var_sum_array    memory [2]
`define _sum_size         32'h50000003
`define offset_sum_size   3
`define var_sum_size      memory [3]
`define _main             32'h50000004
`define offset_main       4
`define var_main          memory [4]
`define state_main        5'd2

// Static, auto and register variables located in module's internal memory
`define main_3_main_array 32'h50000005
`define offset_main_3_main_array 5

module main (reset, clock, master, in_unit, in_address, in_data, in_read, in_call, out_unit,
             out_address, out_data, out_read, out_call );
    input      reset, clock, in_call, in_read;
    output     master, out_read, out_call;
    reg        master, out_read, out_call;

    input [`UNIT_SIZE - 1 : 0] in_unit;
    input [`ADDRESS_SIZE - 1 : 0] in_address;
    input [`DATA_SIZE - 1 : 0] in_data;

    output [`UNIT_SIZE - 1 : 0] out_unit;
    output [`ADDRESS_SIZE - 1 : 0] out_address;
    output [`DATA_SIZE - 1 : 0] out_data;

    reg   [`UNIT_SIZE - 1 : 0] out_unit;
    reg   [`ADDRESS_SIZE - 1 : 0] out_address;
    reg   [`DATA_SIZE - 1 : 0] out_data;

// Module data
    reg   [`STATE_SIZE - 1 : 0] state;
    reg   [`STATE_SIZE - 1 : 0] return_state;
    reg   [WORD_SIZE - 1 : 0] memory [0 : `WORD_MEMORY_SIZE - 1];

```

```

// Predefined states parameter [4:0]
    init      = 5'd0,
    idle     = 5'd20,
    read     = 5'd21,
    write    = 5'd22,
    intercall = 5'd23,
    intercall2 = 5'd24,
    intercall3 = 5'd25,
    answer   = 5'd26,
    answer2  = 5'd27;
// Function result registers
    reg [31:0] result_sum, result_main;
// Static, auto and register variables located on registers
    reg [31:0] main_2_sum_i, main_2_sum_sum, main_3_main_i, main_3_main_size;
// Temporary registers
    reg [31 : 0] _6_32, _8_32, _9_32, _11_32;      reg [ 0 : 0] _7_1, _10_1;
always @ (posedge reset or posedge clock) // Clock cycle
begin
    if (reset)
        begin
            master = 0;
            state = idle;
        end
    else
        begin
            case (state)
                idle: begin
                    if (in_unit == `UNIT_MAIN)
                        begin
                            if (in_call)
                                begin
                                    out_unit = in_unit;
                                    out_address = in_address;
                                    out_data = answer;
                                    return_state = in_address;
                                    state = write;
                                end
                            else
                                begin
                                    out_unit = in_unit;
                                    out_address = in_address;
                                    return_state = answer;
                                    if (in_read)
                                        state = read;
                                    else
                                        begin
                                            out_data = in_data;
                                            state = write;
                                        end
                                end
                            end
                        end
                    end
                end
            end

```

FIG._18B2

```

init: begin
    master = 1;
    state = answer;
end

`state__sum: begin
    main_2_sum_sum = 32'd0;
    main_2_sum_i = 32'd0;
    state = `STATE_SIZE'd11;
end

`STATE_SIZE'd11: begin
    _6_32 = (main_2_sum_i - `var__sum__size);
    _7_1 = _6_32 [31] == 1'b1;
    state = _7_1 ? `STATE_SIZE'd12 : `STATE_SIZE'd13;
end

`STATE_SIZE'd12: begin
    { out_unit, out_address } = (`var__sum__array + main_2_sum_i);
    return_state = `STATE_SIZE'd17;
    state = read;
end

`STATE_SIZE'd17: begin
    _8_32 = out_data;
    main_2_sum_sum = (main_2_sum_sum + _8_32);
    main_2_sum_i = (main_2_sum_i + 32'd1);
    state = `STATE_SIZE'd11;
end

`STATE_SIZE'd13: begin
    result_sum = main_2_sum_sum;
    { out_unit, out_address } = `_sum;
    out_data = result_sum;
    master = 1;
    state = `var__sum;
end

`state_main: begin
    main_3_main_size = 32'd10;
    memory [main_3_main_array - (UNIT_MAIN << `ADDRESS_SIZE)] = 32'd1;
    memory [(main_3_main_array + 32'd1) - (UNIT_MAIN << `ADDRESS_SIZE)] = 32'd2;
    memory [(main_3_main_array + 32'd2) - (UNIT_MAIN << `ADDRESS_SIZE)] = 32'd3;
    main_3_main_i = 32'd3;
    state = `STATE_SIZE'd14;
end

`STATE_SIZE'd14: begin
    _9_32 = (main_3_main_i - main_3_main_size);
    _10_1 = _9_32 [31] == 1'b1;
    state = _10_1 ? `STATE_SIZE'd15 : `STATE_SIZE'd16;
end

```

FIG._ 18B3

```
'STATE_SIZE'd15: begin
    _11_32 = (main_3_main_i << 1'd1);
    { out_unit, out_address } = ( main_3_main_array + main_3_main_i );
    out_data = _11_32;
    return_state = `STATE_SIZE'd18;
    state = write;
end

`STATE_SIZE'd18: begin
    main_3_main_i = (main_3_main_i + 32'd1);
    state = `STATE_SIZE'd14;
end

`STATE_SIZE'd16: begin
    `var__sum__array = `main_3_main_array;
    `var__sum__size = main_3_main_size;
    `var__sum = `STATE_SIZE'd19;
    state = `state__sum;
end

`STATE_SIZE'd19: begin
    result_main = result_sum;
    { out_unit, out_address } = `_main;
    out_data = result_main;
    master = 1;
    state = `var_main;
end

read: begin
    if (out_unit != `UNIT_MAIN)
        begin
            out_read = 1;
            out_call = 0;
            master = 1;
            state = intercall;
        end
    else
        begin
            out_data = memory [out_address];
            if (return_state == answer)
                master = 1;
            state = return_state;
        end
end
end
```

FIG._ 18B4

```
write: begin
    if (out_unit != `UNIT_MAIN)
        begin
            out_read = 0;
            out_call = 0;
            master   = 1;
            state    = intercall;
        end
    else
        begin
            memory [out_address] = out_data;
            if (return_state == answer)
                master = 1;
            state = return_state;
        end
    end
intercall: begin
    state = intercall2;
end
intercall2: begin
    master = 0;
    state = intercall3;
end
intercall3: begin
    if ((in_unit, in_address) == (out_unit, out_address))
        begin
            out_data = in_data;
            state = return_state;
        end
    end
answer: begin
    state = answer2;
end
answer2: begin
    master = 0;
    state = idle;
end
default:
    state = idle;
endcase
end
endmodule
```

FIG._ 18B5

```
int data_in;
int out1;
int out2;
int data_out;

void pipeline_stage_1 ()
{
    while (data_in != 0)
        out1 = data_in + 1;

    if (data_in == 1)
        while (data_in == 1)
            out1 = 2;
}

void pipeline_stage_2 ()
{
    while (out1 == 0)
        out2 = 0;

    while (out1 != 0)
        out2 = out1 + 1;
}

void pipeline_stage_3 ()
{
    if (out2 == 1)
        while (out2 == 1)
            data_out = 2;

    while (out2 != 0)
        data_out = out2 + 1;
}

#ifndef __SYNETRY__

#include <stdio.h>

void main ()
{
    for (;;)
    {
        scanf ("%d", & data_in);
        pipeline_stage_1 ();
        pipeline_stage_2 ();
        pipeline_stage_3 ();
        printf ("%d", data_out);
    }
}

#endif
```

FIG._19A

```

module Pipeline(clock,reset,_data_in,_data_out,run_pipeline_stage_1,ready_pipeline_stage_1,
               run_pipeline_stage_2,ready_pipeline_stage_2,run_pipeline_stage_3,ready_pipeline_stage_3);
  input      clock, reset, run_pipeline_stage_1, run_pipeline_stage_2, run_pipeline_stage_3;
  input [15:0] _data_in;
  output     ready_pipeline_stage_1, ready_pipeline_stage_2, ready_pipeline_stage_3;
  output [15:0] _data_out;
  reg        ready_pipeline_stage_1, ready_pipeline_stage_2, ready_pipeline_stage_3;
  reg [2:0]   state1, state2, state3;
  reg [15:0]  _data_out, _out1, _out2;

  always @(posedge clock)
  begin
    if (reset)
      state1 = 0;
    else
      begin
        case (state1)

          0: begin
            if (run_pipeline_stage_1)
              begin
                ready_pipeline_stage_1 = 0;
                state1 = 1;
              end
            end
          end

          1: state1 = (_data_in != 16'd0) ? 2 : 3;

          2: begin
            _out1 = (_data_in + 16'd1);
            state1 = 1;
          end

          3: state1 = (_data_in == 16'd1) ? 4 : 6;

          4: state1 = (_data_in == 16'd1) ? 5 : 6;

          5: begin
            _out1 = 16'd2;
            state1 = 4;
          end

          6: begin
            ready_pipeline_stage_1 = 1;
            state1 = 0;
          end

          default: ;

        endcase
      end
    end
  
```

FIG._ 19B1

```
always @(posedge clock)
begin
    if (reset)
        state2 = 0;
    else
        begin
            case (state2)
                0: begin
                    if (run_pipeline_stage_2)
                        begin
                            ready_pipeline_stage_2 = 0;
                            state2 = 1;
                        end
                    end
                end
                1: state2 = (_out1 == 16'd0) ? 2 : 3;
                2: begin
                    _out2 = 16'd0;
                    state2 = 1;
                end
                3: state2 = (_out1 != 16'd0) ? 4 : 5;
                4: begin
                    _out2 = (_out1 + 16'd1);
                    state2 = 3;
                end
                5: begin
                    ready_pipeline_stage_2 = 1;
                    state2 = 0;
                end
                default: ;
            endcase
        end
    end
```

FIG._ 19B2

```

always @(posedge clock)
begin
    if (reset)
        state3 = 0;
    else
        begin
            case (state3)

                0: begin
                    if (run_pipeline_stage_3)
                        begin
                            ready_pipeline_stage_3 = 0;
                            state3 = (_out2 == 16'd1) ? 1 : 3;
                        end
                end

                1: state3 = (_out2 == 16'd1) ? 2 : 3;

                2: begin
                    _data_out = 16'd2;
                    state3 = 1;
                end

                3: state3 = (_out2 != 16'd0) ? 4 : 5;

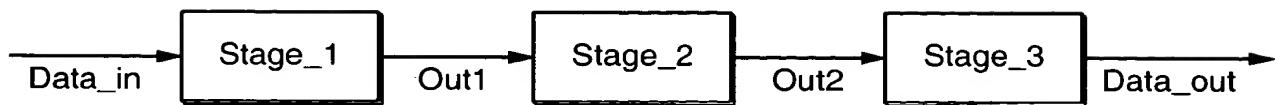
                4: begin
                    _data_out = (_out2 + 16'd1);
                    state3 = 3;
                end

                5: begin
                    ready_pipeline_stage_3 = 1;
                    state3 = 0;
                end

                default: ;

            endcase
        end
    end
endmodule

```

FIG._ 19B3***FIG._ 19C***

```
#include <stdio.h>

typedef enum { true = 1, false = 0 } bool;

void main ()
{
    bool bLightIsOn = true;

    printf ("Light.c - C program working on APS-X84 FPGA test card\n");

    for (;;)
    {
        int counter;

        printf
        (
            "Enter the number of clock ticks"
            " to wait before the light change: "
        );

        scanf ("%d", & counter);

        if (counter < 0)
            counter = 0;

        while (counter -- != 0)
            printf ("Waiting...\n");

        bLightIsOn = ! bLightIsOn;

        printf ("Light is: %d\n", bLightIsOn);
    }
}
```

FIG._20A

```

module Light (clock, reset, scanf_0_1_line_33_counter, printf_4_1_line_43_bLightIsOn,
              run_main, ready_main );
  input      clock, reset, run_main;
  input [ 7:0] scanf_0_1_line_33_counter;

  output      ready_main;
  output [ 1:0] printf_4_1_line_43_bLightIsOn;
  reg         ready_main, _1_1;
  reg [ 1:0]  printf_4_1_line_43_bLightIsOn, _3_main_bLightIsOn, 3_2;
  reg [ 2:0]  state;
  reg [ 7:0]  _4_main_counter, _2_8;

  always @(posedge clock)
  begin
    if (reset)
      state = 0;
    else
      begin
        case (state)
          0: begin
            if (run_main)
              begin
                ready_main = 0;
                _3_main_bLightIsOn = 2'd1;
                // User Verilog code
                $write ("Light.c - C program working on APS-X84 FPGA test card\n");
                // End of user Verilog code
                state = 1;
              end
            end
          end
          1: begin
            // User Verilog code
            $write ("Enter the number of clock ticks to wait before the light change: ");
            // End of user Verilog code
            _4_main_counter = scanf_0_1_line_33_counter;
            _1_1 = _4_main_counter [7] == 1'b1;
            if (_1_1)
              _4_main_counter = 8'd0;
            state = 2;
          end
          2: begin
            _2_8 = _4_main_counter;
            _4_main_counter = (_2_8 - 8'd1);
            state = (_2_8 != 8'd0) ? 3 : 4;
          end
        endcase
      end
    end
  end
endmodule

```

FIG._20B1

```

3: begin
    // User Verilog code
    $write ("Waiting...\n");
    // End of user Verilog code
    state = 2;
end

4: begin
    _3_2 = (! _3_main_bLightIsOn);
    _3_main_bLightIsOn = _3_2;
    printf_4_1_line_43_bLightIsOn = _3_main_bLightIsOn;
    // User Verilog code
    $write ("Light is: %d\n", printf_4_1_line_43_bLightIsOn);
    // End of user Verilog code
    state = 1;
end

default: ;

endcase
end
end

endmodule

//  APSX84.v - Verilog wrapper module which instantiates module Light.v.
//      This design is intended to run on APS-X84 board.
//

module APSX84 ( clock, clock_enable, reset, data, LCD);

    input      clock      /* synthesis xc_loc=P24 */;
    input      clock_enable /* synthesis xc_loc=P3 */;
    input      reset      /* synthesis xc_loc=P4 */;
    input [5:0] data       /* synthesis xc_loc="P10,P9,P8,P7,P6,P5" */;
    output     LCD        /* synthesis xc_loc=P35 */;

    wire      internal_clock = clock & clock_enable;
    wire [7:0] data8 = { data, 2'b0 };
    wire [1:0] LCD2;
    wire      LCD = LCD2 [0];
    wire      run_main = 1;

    Light Light ( internal_clock, reset, data8, LCD2, run_main,);

endmodule

```

FIG._20B2

```

int sum (int n)
{
    int i, sum = 0;
    for (i = 0; i != n; i++)
        sum += i;
    return sum;
}

```

FIG._21A

```

module Sum (clock, reset, result_sum, param_sum_n, run_sum, ready_sum );
    input      clock, reset, run_sum;
    input [15:0] param_sum_n;
    output     ready_sum;
    output [15:0] result_sum;
    reg       ready_sum;
    reg [1:0]  state;
    reg [15:0] result_sum, s_2_sum_i, s_2_sum_sum;

always @(posedge clock)
begin
    if (reset)
        state = 0;
    else
begin
    case (state)
        0: begin
            if (run_sum)
begin
                ready_sum = 0;
                s_2_sum_sum = 16'd0;
                s_2_sum_i = 16'd0;
                state = 1;
end
end
        1: state = (s_2_sum_i != param_sum_n) ? 2 : 3;
        2: begin
            s_2_sum_sum = (s_2_sum_sum + s_2_sum_i);
            s_2_sum_i = (s_2_sum_i + 16'd1);
            state = 1;
end
        3: begin
            result_sum = s_2_sum_sum;
            ready_sum = 1;
            state = 0;
end
        default: ;
    endcase
end
end
endmodule

```

FIG._21B

```

library IEEE;
use IEEE.STD_Logic_1164.all;
use IEEE.Numeric_Std.all;

entity synetry_sum is
port( clock      : in std_logic;
      reset      : in boolean;
      run_sum    : in boolean;
      param_sum_n : in integer range 0 to 65535;
      result_sum : out integer range 0 to 65535;
      ready_sum  : out boolean );
end entity synetry_sum;

architecture RTL of synetry_sum is
begin
  process_synetry_sum : process
    variable state      : integer range 0 to 3;
    variable s_2_sum_i  : integer range 0 to 65535;
    variable s_2_sum_sum : integer range 0 to 65535;
  begin
    wait until clock'event and clock = '1';
    if (reset) then
      state := 0;
    else
      case (state)is
        when 0 =>
          if (run_sum)then
            ready_sum <= false;
            s_2_sum_sum := 0;
            s_2_sum_i := 0;
            state := 1;
          end if;
        when 1 =>
          if (s_2_sum_i /= param_sum_n) then
            state := 2;
          else
            state := 3;
          end if;
        when 2 =>
          s_2_sum_sum := s_2_sum_sum + s_2_sum_i;
          s_2_sum_i := s_2_sum_i + 1;
          state := 1;
        when 3 =>
          result_sum <= s_2_sum_sum;
          ready_sum <= true;
          state := 0;
      end case;
    end if;
    wait;
  end process process_synetry_sum;
end architecture RTL;

```

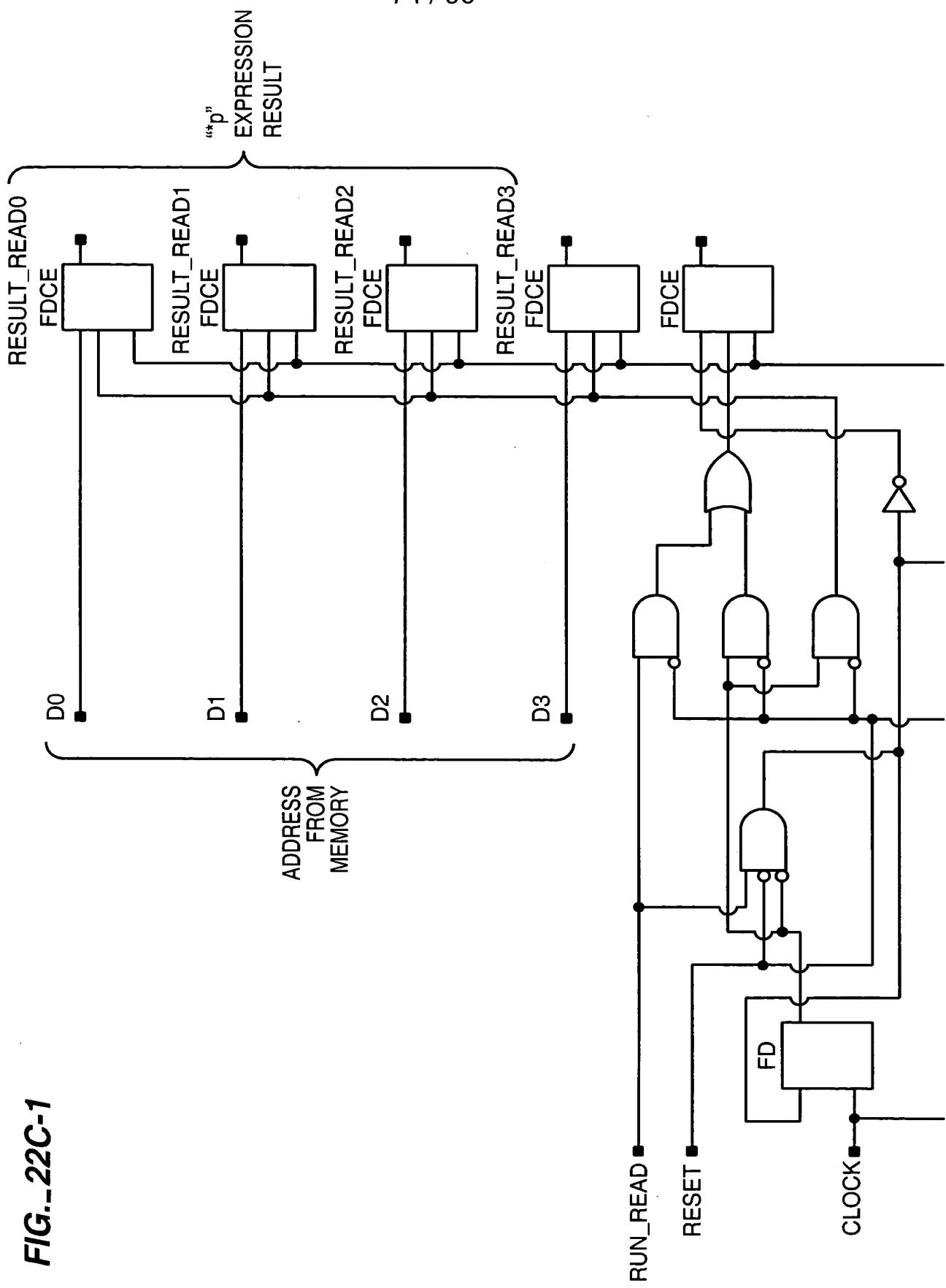
```
int read (int * p)
{
    return * p;
}
```

FIG._22A

```
module Read(clock,reset,a,d,o,we,result_read,param_read_p,run_read,ready_read);
    input      clock, reset, run_read;
    input [ 3:0] o, param_read_p;
    output     we, ready_read;
    output [ 3:0] a, d, result_read;
    reg        we, ready_read, state;
    reg [ 3:0] a, d, result_read;

    always @(posedge clock)
    begin
        if (reset)
        begin
            we = 0;
            state = 0;
        end
        else
        begin
            case (state)
                0:begin
                    if (run_read)
                    begin
                        ready_read = 0;
                        a = param_read_p;
                        state = 1;
                    end
                end
                1:begin
                    _1_4 = o;
                    result_read = _1_4;
                    ready_read = 1;
                    state = 0;
                end
                default: ;
            endcase
        end
    end
endmodule
```

FIG._22B



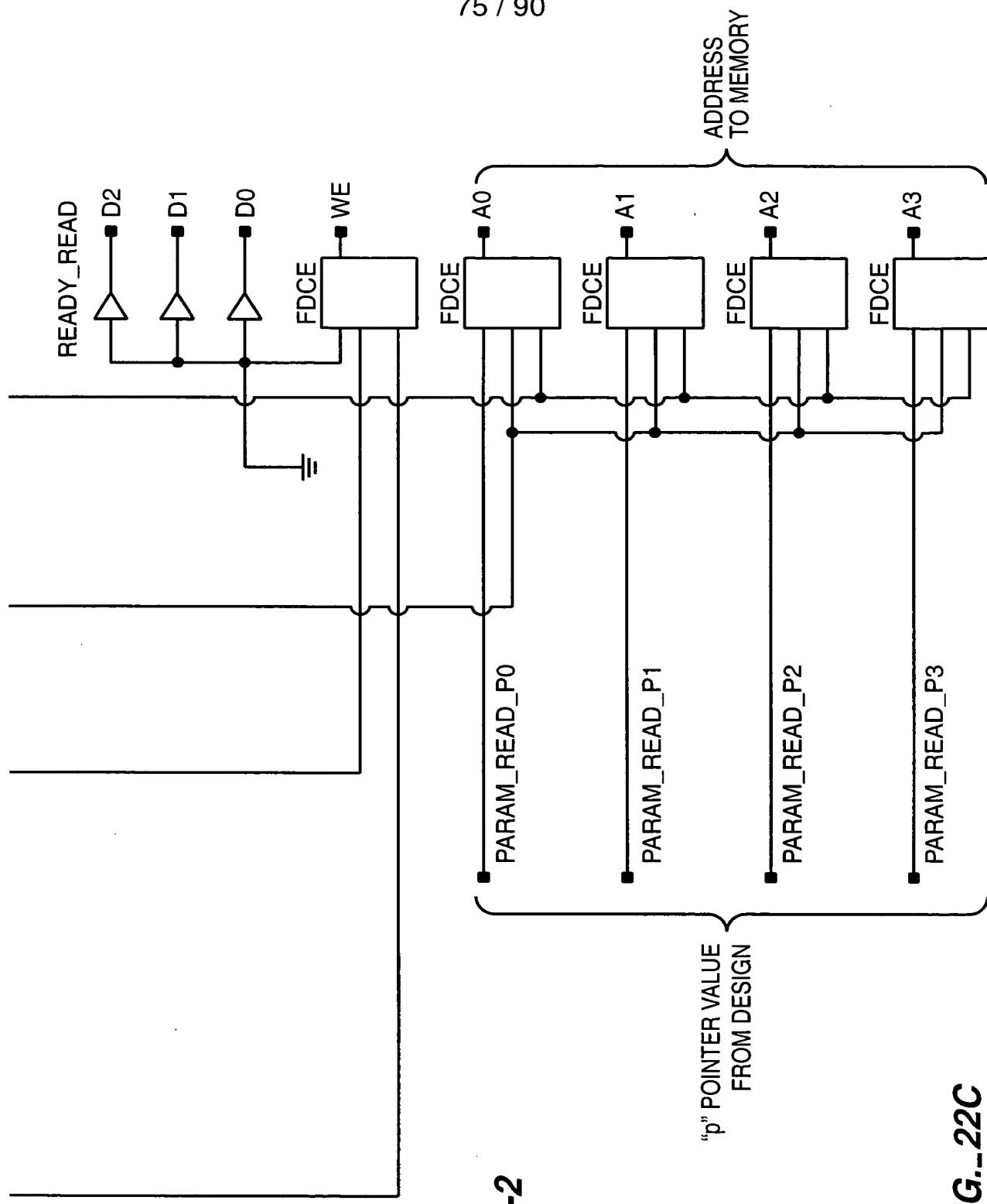


FIG. 22C-2

FIG. 22C-1

FIG. 22C-2 FIG. 22C

```
void write (int * p, int d)
{
    * p = d;
}
```

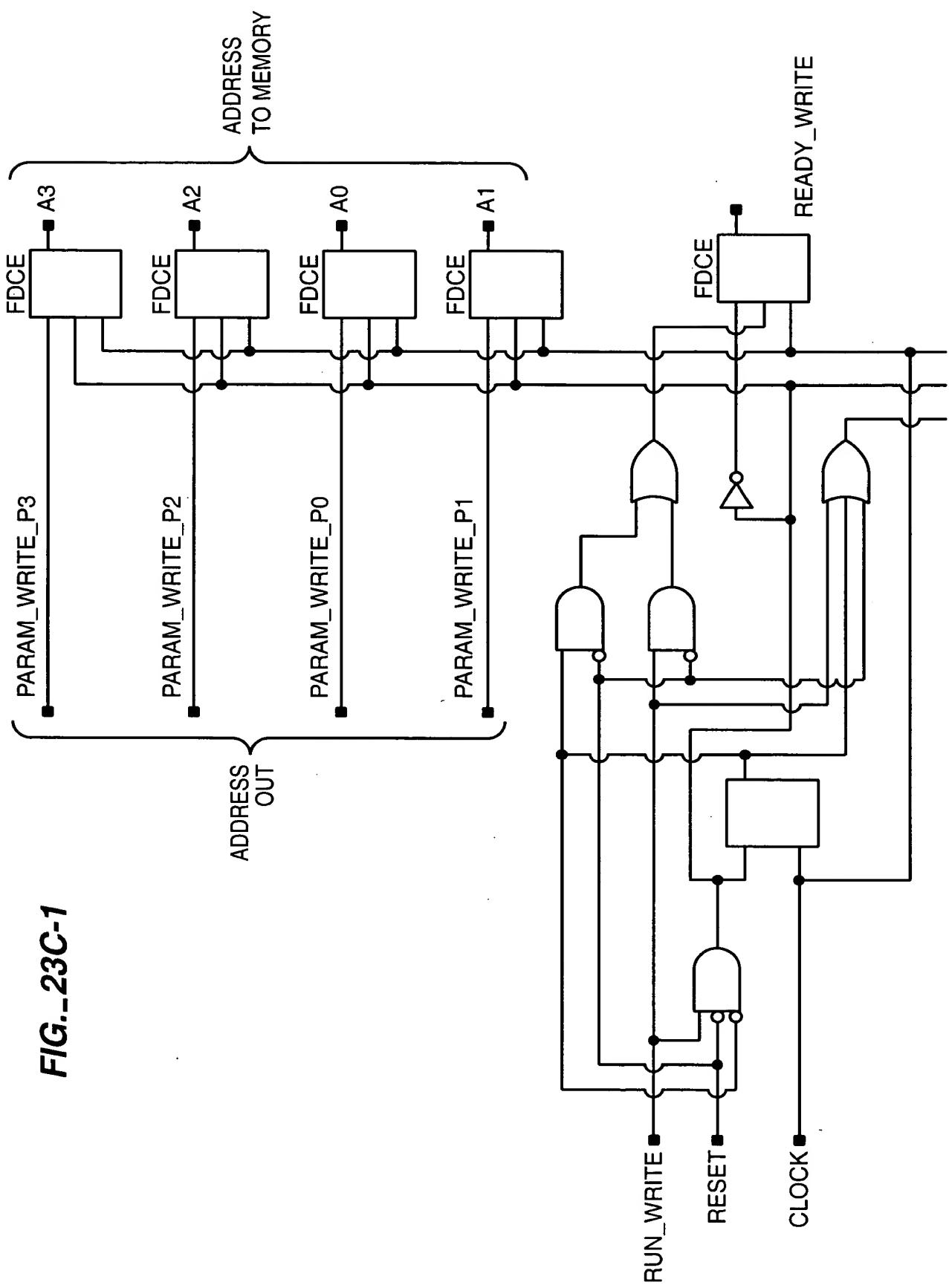
FIG._23A

```
module Write(clock,reset,a,d,o,we,param_write_p,param_write_d,run_write,ready_write);
input      clock, reset, run_write;
input [ 3:0] o, param_write_p, param_write_d;
output     we, ready_write;
output [ 3:0] a, d;
reg       we, ready_write, state;
reg [ 3:0] a, d;

always @ (posedge clock)
begin
    if (reset)
        begin
            we = 0;
            state = 0;
        end
    else
        begin
            case (state)
                0:begin
                    if (run_write)
                        begin
                            ready_write = 0;
                            a = param_write_p;
                            d = param_write_d;
                            we = 1;
                            state = 1;
                        end
                end
                1:begin
                    we = 0;
                    ready_write = 1;
                    state = 0;
                end
                default: ;
            endcase
        end
end
endmodule
```

FIG._23B

FIG.-23C-1



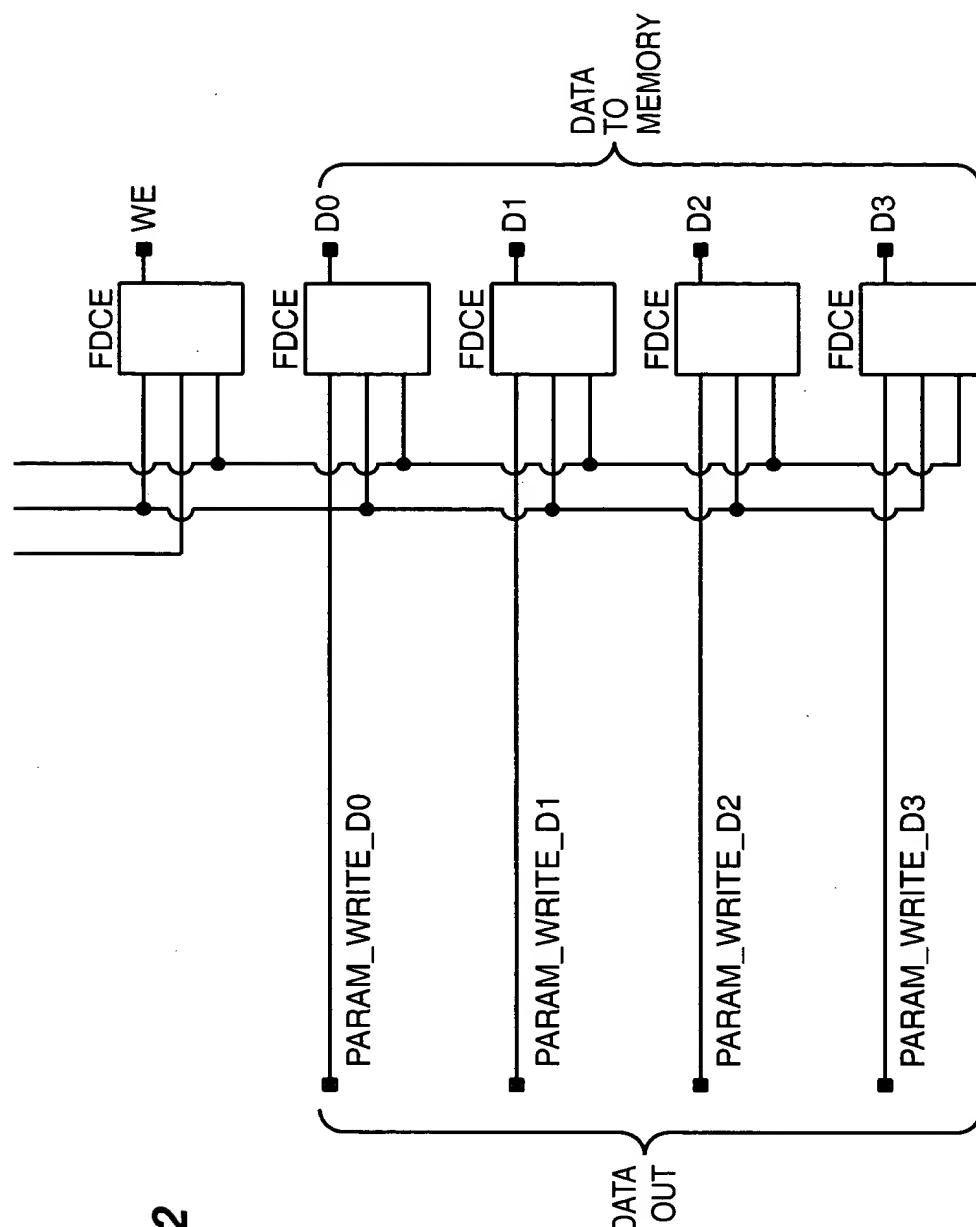


FIG..23C-2

FIG..23C-1

FIG..23C-2

FIG..23C

```

typedef struct
{
    int a;
    int b;
} STRUCTURE;

int read_member_b (STRUCTURE *p)
{
    return p -> b;
}

```

FIG._24A

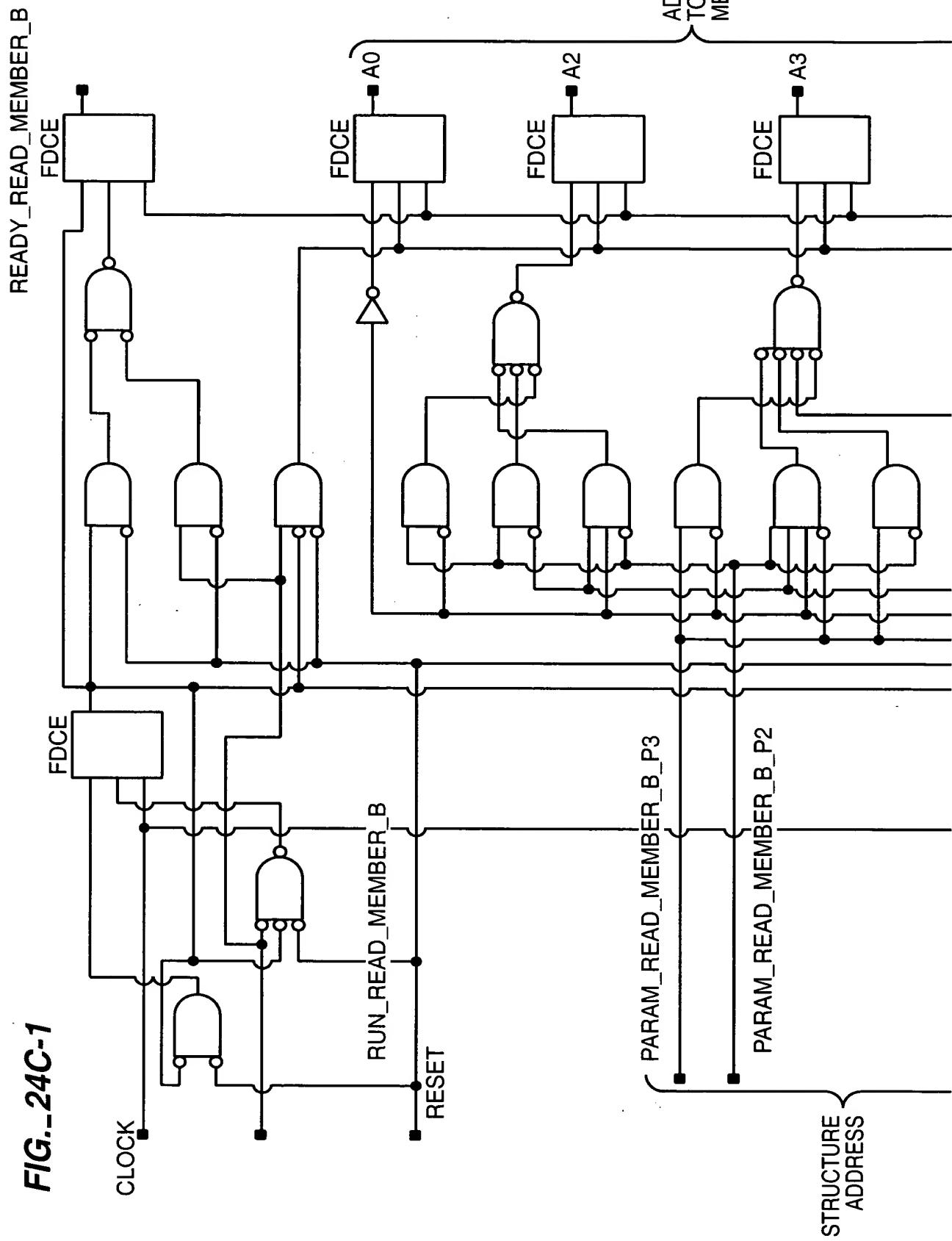
```

module Struct1(clock,reset,a,d,o,we,result_read_member_b,param_read_member_b_p,
              run_read_member_b,ready_read_member_b);
    input      clock, reset, run_read_member_b;
    input [ 3:0] o, param_read_member_b_p;
    output     we, ready_read_member_b;
    output [ 3:0] a, d, result_read_member_b;
    reg        we, ready_read_member_b, state;
    reg [ 3:0] a, d, result_read_member_b, _1_4;

    always @(posedge clock)
    begin
        if (reset)
        begin
            we = 0;
            state = 0;
        end
        else
        begin
            case (state)
                0:begin
                    if (run_read_member_b)
                    begin
                        ready_read_member_b = 0;
                        a = (param_read_member_b_p + 4'd1);
                        state = 1;
                    end
                end
                1:begin
                    _1_4 = o;
                    result_read_member_b = _1_4;
                    ready_read_member_b = 1;
                    state = 0;
                end
                default: ;
            endcase
        end
    end
endmodule

```

FIG._24B



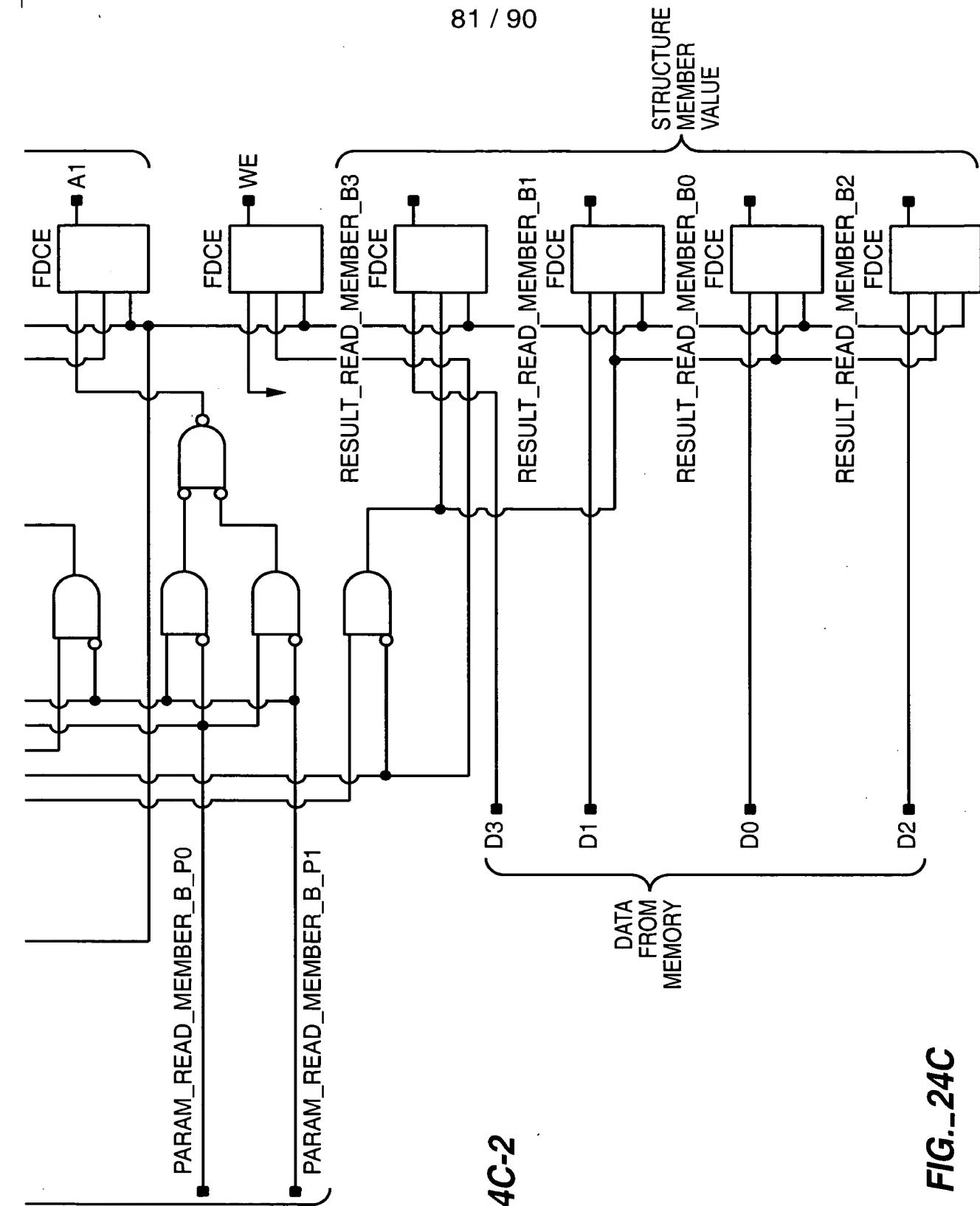


FIG. 24C-2

FIG. 24C-1

FIG. 24C

```

typedef struct
{
    int a;
    int b;
} STRUCTURE;

void write_member_b (STRUCTURE *p, int n)
{
    p -> b = n;
}

```

FIG._25A

```

module Struct2(clock,reset,a,d,o,we,param_write_member_b_p,param_write_member_b_n,
              run_write_member_b,ready_write_member_b);
    input      clock, reset, run_write_member_b;
    input [ 3:0] o, param_write_member_b_p, param_write_member_b_n;
    output     we, ready_write_member_b;
    output [ 3:0] a, d;
    reg        we, ready_write_member_b, ready_write_member_b, state;
    reg [ 3:0] a, d;

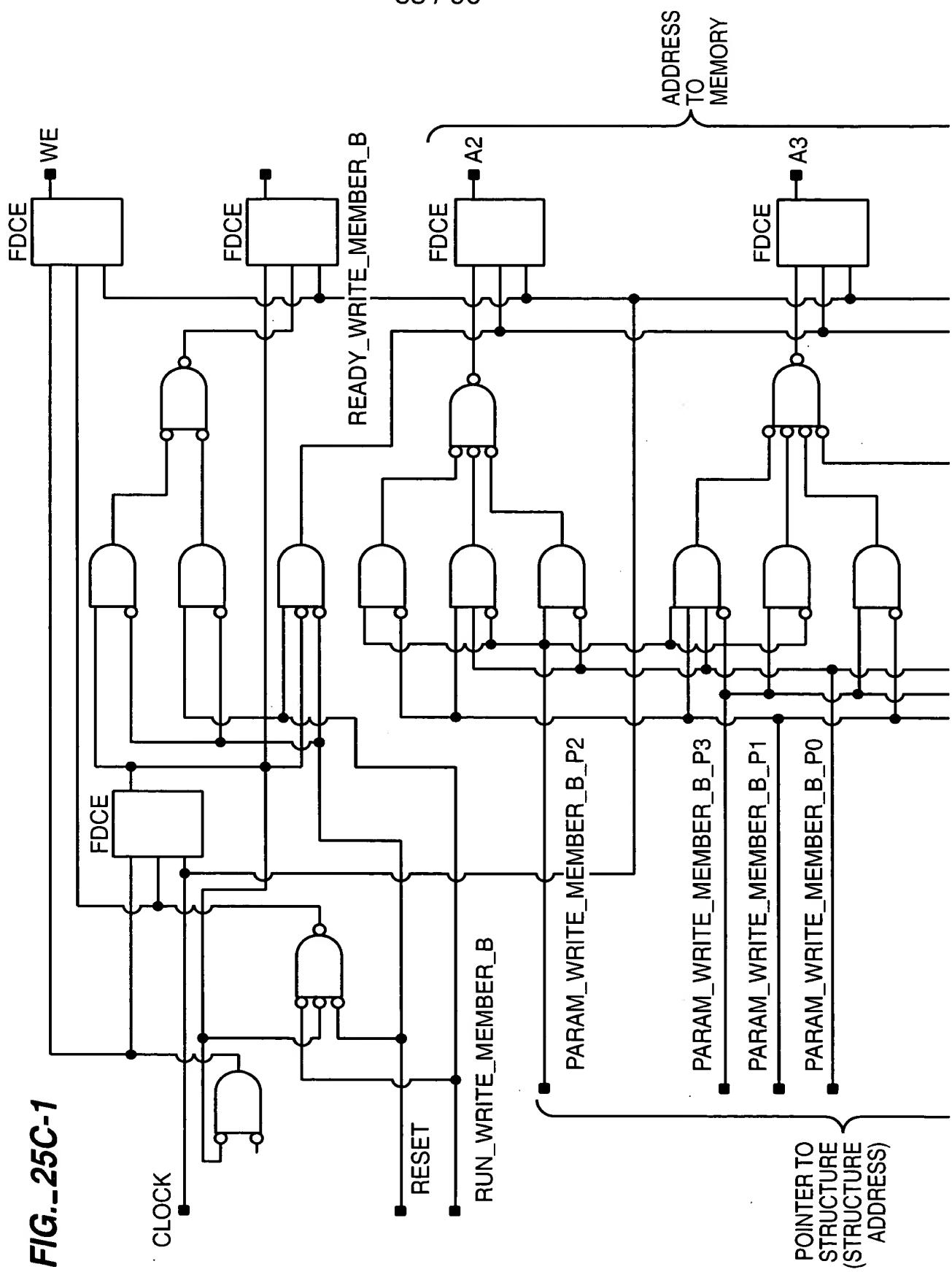
    always @(posedge clock)
    begin
        if (reset)
            begin
                we = 0;
                state = 0;
            end
        else
            begin
                case (state)
                    0:begin
                        if (run_write_member_b)
                            begin
                                ready_write_member_b = 0;
                                a = (param_write_member_b_p + 4'd1);
                                d = param_write_member_b_n;
                                we = 1;
                                state = 1;
                            end
                    end
                    1:begin
                        we = 0;
                        ready_write_member_b = 1;
                        state = 0;
                    end
                    default: ;
                endcase
            end
    end
endmodule

```

FIG._25B

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FIG.-25C-1



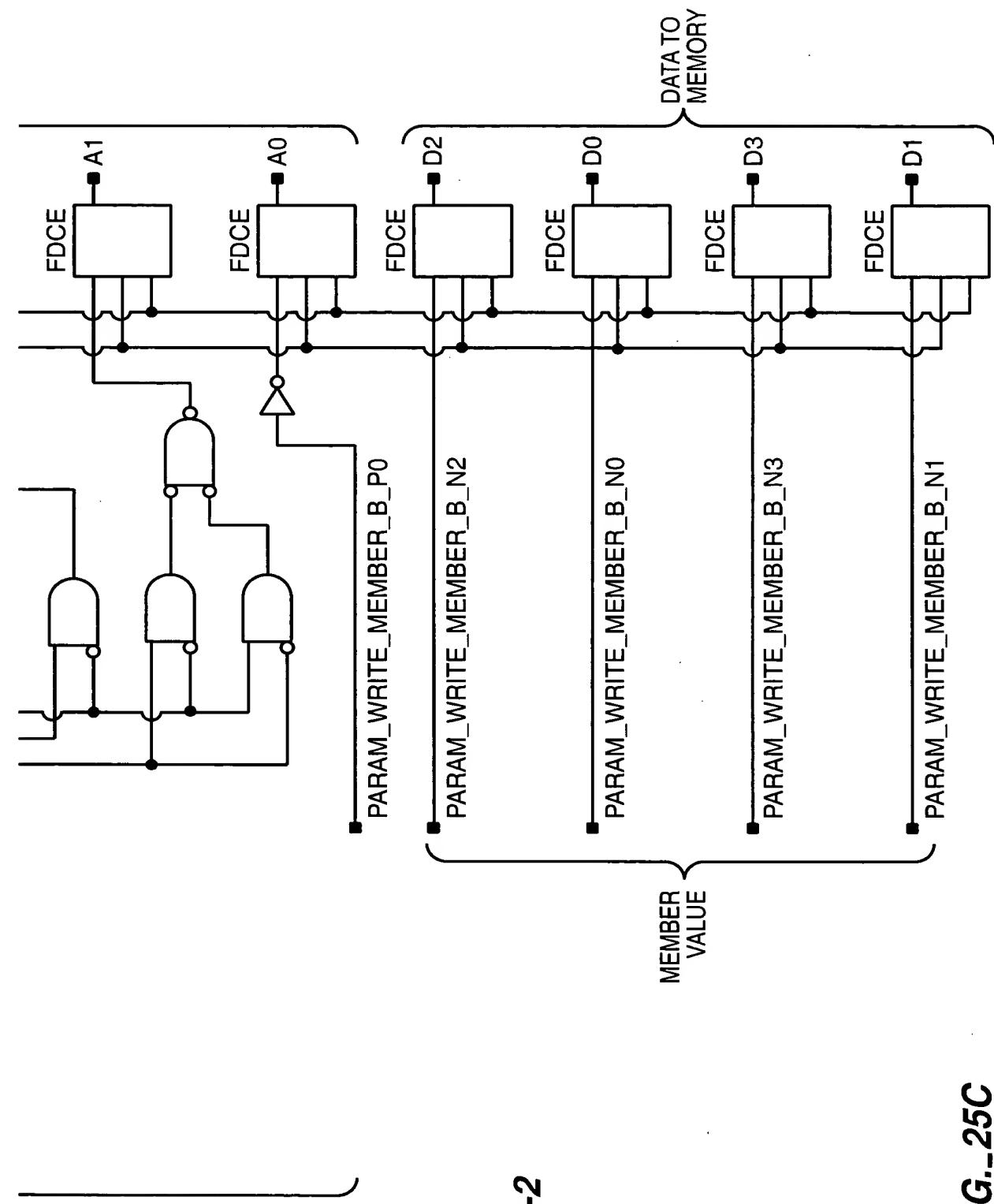


FIG. 25C-2

FIG. 25C-1

FIG. 25C-2 FIG. 25C

```

typedef struct
{
    int a;
    int b;
} STRUCTURE;
STRUCTURE s;
int read_member_b (void)
{
    return s.b;
}

```

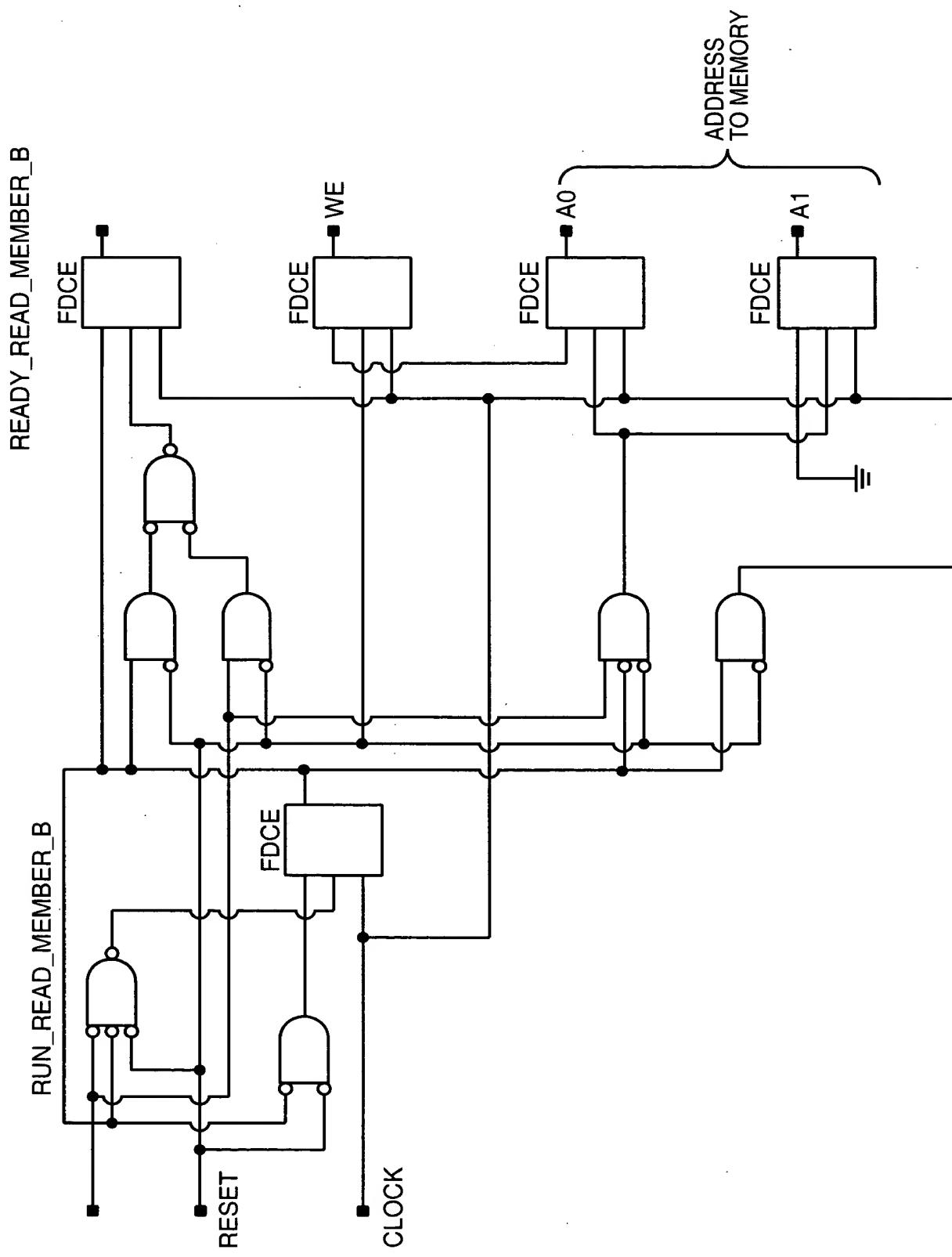
FIG._26A

```

`define _s 2'h1
module Struct4(clock,reset,a,d,o,we,result_read_member_b,run_read_member_b,ready_read_member_b);
    input      clock, reset, run_read_member_b;
    input [ 3:0] o;
    output     we, ready_read_member_b;
    output [ 1:0] a, d, result_read_member_b;
    reg        we, ready_read_member_b, state;
    reg [ 1:0] a, d, result_read_member_b;
    reg [ 3:0] _1_4 ;
    always @(posedge clock)
    begin
        if (reset)
        begin
            we = 0;
            state = 0;
        end
        else
        begin
            case (state)
                0: begin
                    if (run_read_member_b)
                    begin
                        ready_read_member_b = 0;
                        a = (_s + 4'd1);
                        state = 1;
                    end
                end
                1: begin
                    _1_4 = o;
                    result_read_member_b = _1_4;
                    ready_read_member_b = 1;
                    state = 0;
                end
                default: ;
            endcase
        end
    end
endmodule

```

FIG._26B

FIG.-26C-1

"F00Eh0" 2609h60

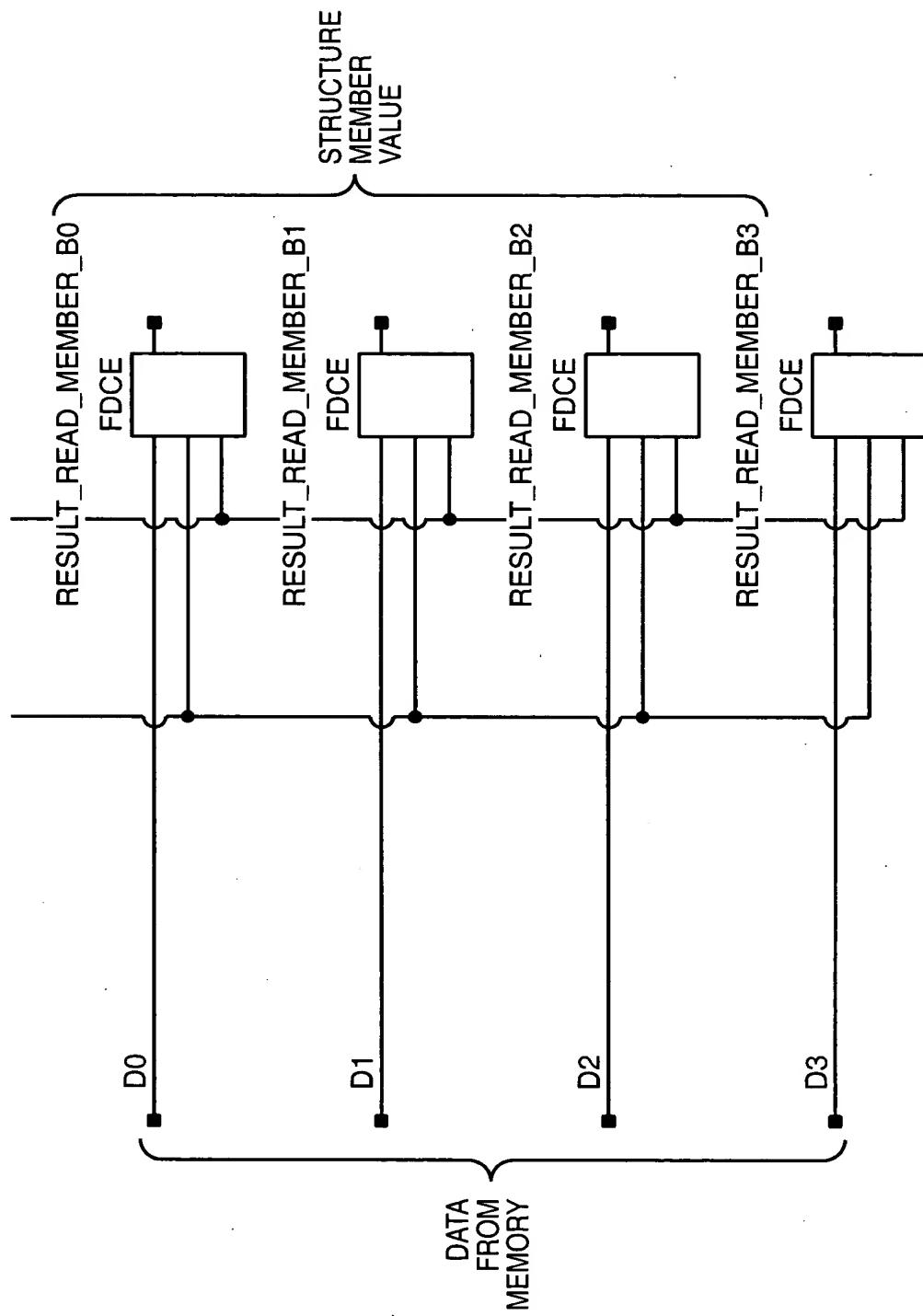


FIG. 26C-2

FIG. 26C-1

FIG. 26C-2

FIG. 26C

```

typedef struct
{
    int a;
    int b;
} STRUCTURE;
STRUCTURE s;
void write_member_b (int n)
{
    s.b = n;
}

```

FIG._27A

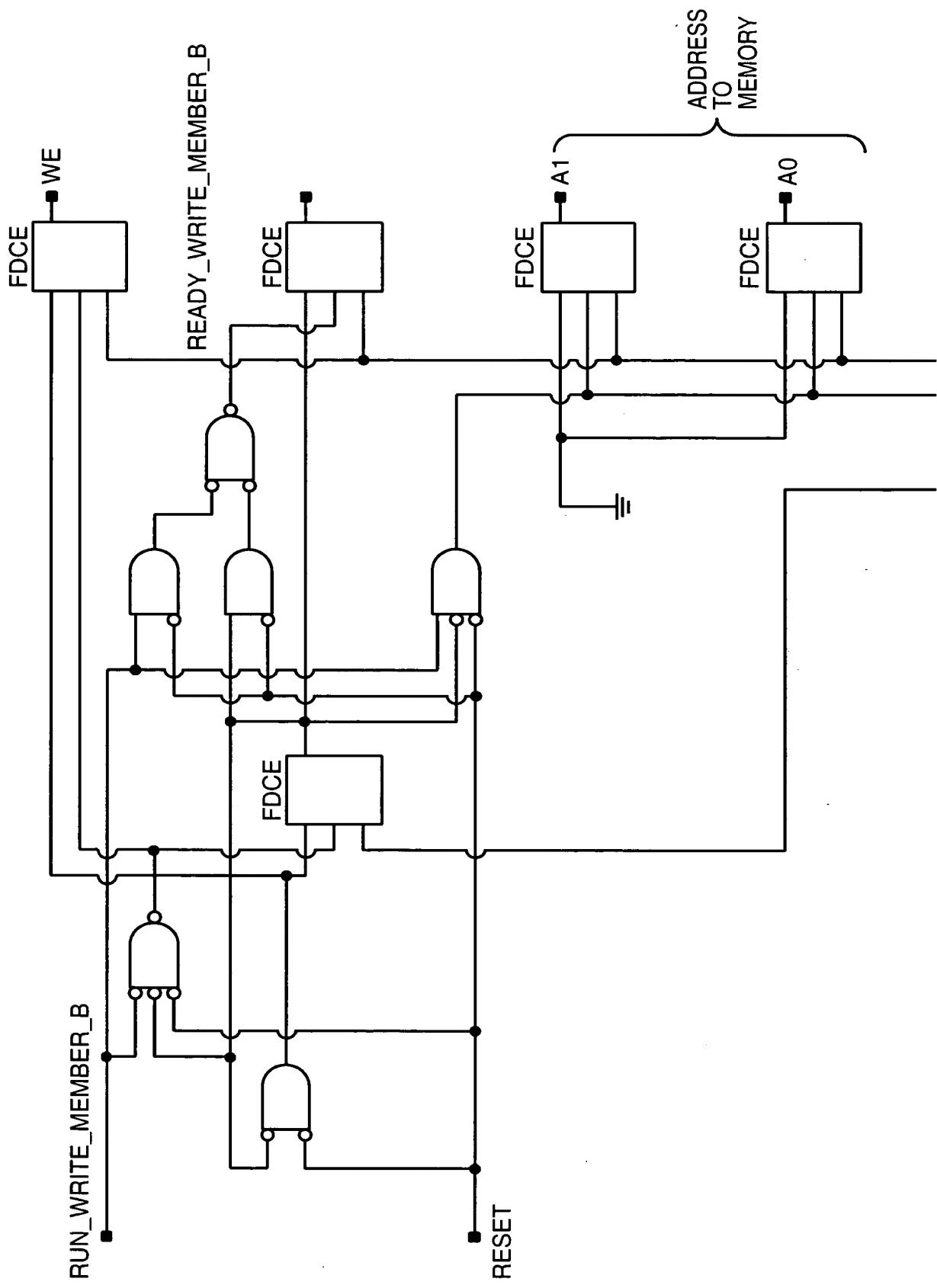
```

`define _s 2'h1
module Struct5(clock,reset,a,d,o,we,param_write_member_b_n,run_write_member_b,ready_write_member_b);
    input      clock, reset, run_write_member_b;
    input [ 3:0] param_write_member_b_n, o;
    output     we, ready_write_member_b;
    output [ 1:0] a;
    output [ 3:0] d;
    reg        we, ready_write_member_b, state;
    reg [ 1:0] a;
    reg [ 3:0] d;
    always @(posedge clock)
    begin
        if (reset)
        begin
            we = 0;
            state = 0;
        end
        else
        begin
            case (state)
                0: begin
                    if (run_write_member_b)
                    begin
                        ready_write_member_b = 0;
                        a = ('_s + 4'd1);
                        d = param_write_member_b_n;
                        we = 1;
                        state = 1;
                    end
                end
                1: begin
                    we = 0;
                    ready_write_member_b = 1;
                    state = 0;
                end
            default: ;
        endcase
        end
    end
endmodule

```

FIG._27B

FIG.-27C-1



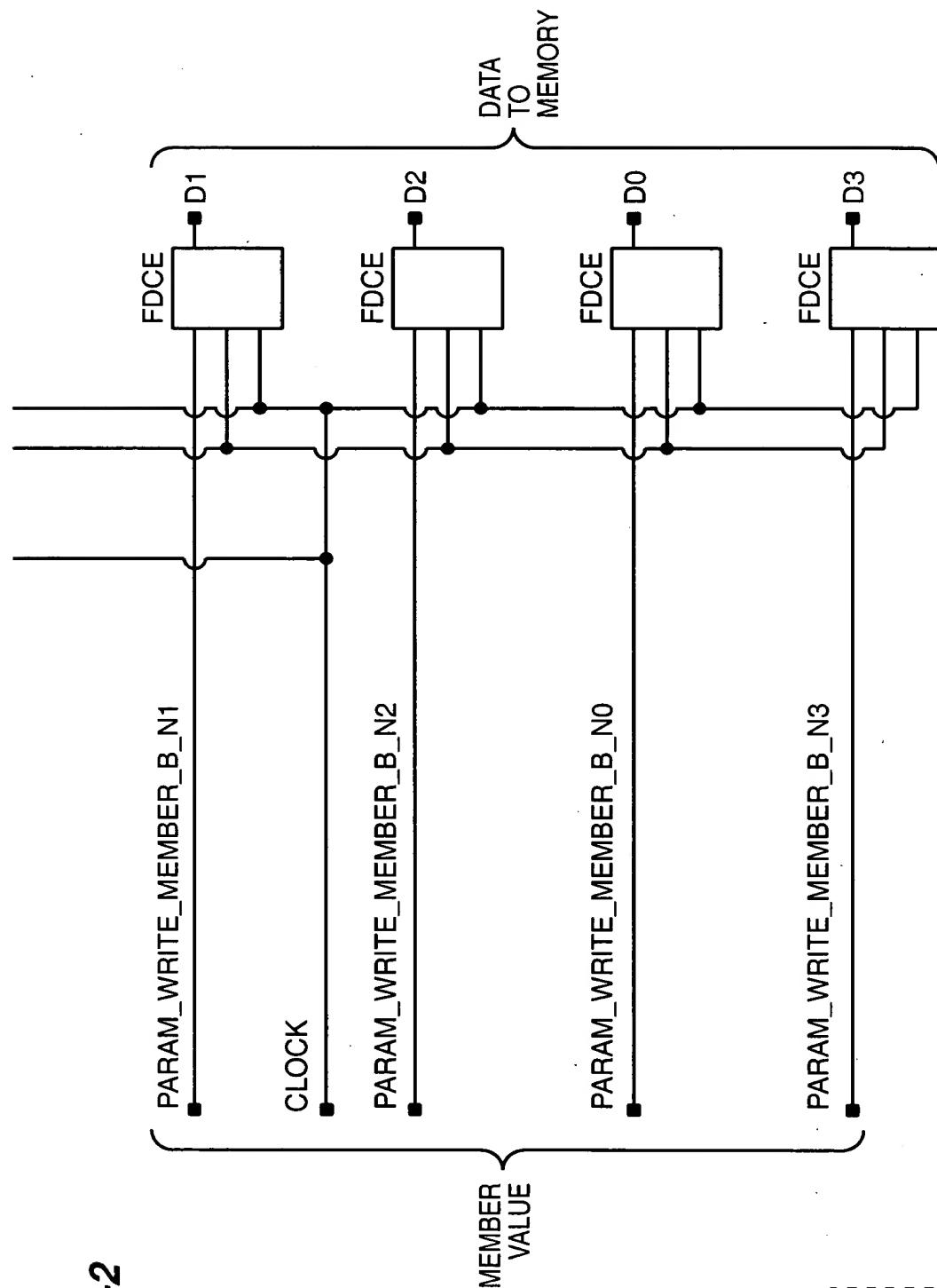


FIG.-27C-2

FIG.-27C-1

FIG.-27C-2

FIG.-27C